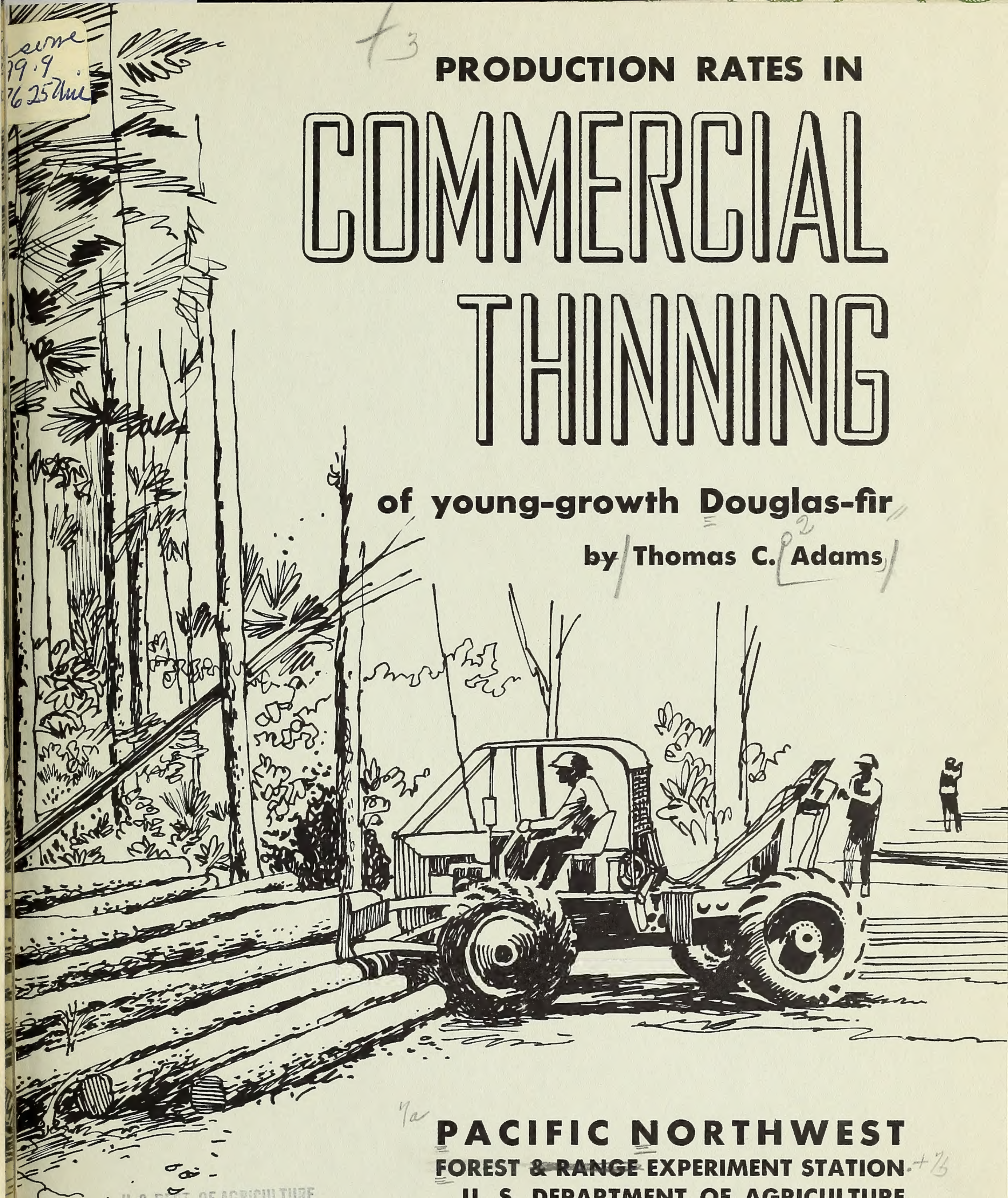
PRODUCTION RATES IN COMMERCIAL THINNING of young-growth Douglas-fir

by Thomas C. Adams



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Acknowledgment

This study of commercial thinning operations was carried out in cooperation with a number of industrial forest-land owners and public forest agencies, who made the operations on their lands available for study and provided data on log production. Their cooperation is gratefully acknowledged. Chief cooperators were Crown Zellerbach Corp., St. Regis Paper Co., Simpson Timber Co., Willamette Industries, Inc. (formerly, Willamette Valley Lumber Co.), and the U. S. Bureau of Land Management.

Machine rates were developed from data supplied by equipment dealers, manufacturers, and logging operators.

Although not contributing data directly to this study, other thinning operations of the U.S. Forest Service, Oregon State University's McDonald Forest, and individual forest-land owners were visited by the author. These helped provide a basis for the overall approach used in the study.

Supervisors and field foresters of cooperators were, in every case, enthusiastic about thinning and especially helpful in contributing toward a point of view of commercial thinning as a business operation as well as a silvicultural measure.

Summary

This study has identified the variable factors affecting production rates of commercial thinning and gives a basis for estimating logging costs over a wide range of situations. Time studies were made of the individual steps in commercial thinning operations: felling, bucking, skidding, and loading. Equations were developed expressing time study results in terms of (1) log and tree volume in cubic feet and board feet, (2) several stand variables, and (3) alternative types of logging equipment.

Labor costs and machine rates were applied to the times per unit of production to give direct costs of logging, by log size. By combining direct logging costs with overhead, road construction, and other fixed costs, the total logging costs can be estimated.

The specific findings of this study were:

1. After an initial thinning, some cost savings can be expected in subsequent thinnings.
2. Low volumes per turn or per log tend to give sharply increased unit costs.
3. Under favorable conditions, logs as small as 2.5 cubic feet or 10 board feet can be carried along with turns of larger logs at no additional cost for a portion of the skidding cycle. By themselves, these logs would be uneconomic; however, under the conditions described, they are, in effect, bonus logs.
4. All logs other than bonus logs must bear the direct costs for the full amount of their handling from the woods to the mill. If it is assumed that log value at the mill is $55 per thousand board feet, the lower limit of economic merchantability under the conditions studied, which included 400 feet of skidding, a 30-mile truck haul, and no stumpage charge, would be approximately 7 cubic feet or 30 board feet.

Other considerations can also influence logging utilization and the marginal log decision. The landowner, for example, may have a special concern over controlling the amount of slash left on the ground, the general appearance of the landscape, or the relation between logging utilization and site preparation for the new crop.

Introduction

This study deals with **commercial thinning** undertaken not only as a cultural measure but also as a business activity. The emphasis here is on thinning as a form of extra yield and extra current income, with thinning costs an important factor in determining the feasibility of marketing and utilization of such material (figs. 1 and 2).

The general silvicultural and economic basis for thinning Douglas-fir, together with discussion of marking guides, has been treated elsewhere (Worthington and Staebler 1961).

Figure 1.—Commercial thinnings add to the region's annual cut. Saw logs are the principal product.

Figure 2.—A 65-hp. tractor decks saw logs at edge of the landing.

Description of Field Studies

This study was conducted during the period 1961 to 1965 on commercial thinning operations in western Washington and western Oregon. Operations were near the following locations, with cooperating landowners as shown:

Vernonia, Oregon (Crown Zellerbach Corp.)
Sheridan, Oregon (U.S. Bureau of Land Management)
Carlton, Oregon (Willamette Industries, Inc.)
Puyallup, Washington (St. Regis Paper Co.)
Shelton, Washington (Simpson Timber Co.)
Cathlamet, Washington (Crown Zellerbach Corp.)

Study areas were selected to represent moderately even-age stand conditions, with slopes generally under 40 percent.

Age of stands varied between 35 and 75 years. Timber volumes averaged 6,993 net cubic feet per acre (trees 5 inches and larger, d.b.h.[1]) in the stands that had not been thinned previously, and 6,526 net cubic feet per acre in those stands previously thinned (table 1). Corresponding net board-foot volumes were 31,195 and 30,535 board feet per acre, respectively (Scribner scale[2], trees 11 inches and larger d.b.h.).

Skidding, commonly called yarding, was by 40- to 65-horsepower crawler tractors or by four-wheeled rubber-tired skidders. The designated horsepower refers to net engine or belt horsepower.[3] Except for a few scattered observations, the crawler tractors were equipped with bulldozer blade and arch.

Table 1.—Stand characteristics of study settings[1]

Stand characteristics[2]	Number of settings	Mean	Range
Net volume per acre:		Cubic feet	
Unthinned	19	6,993	3,289 to 12,011
Previously thinned	16	6,526	3,176 to 9,980
Basal area per acre:		Square feet	
Unthinned	19	188	91 to 260
Previously thinned	16	167	84 to 248
Trees per acre:		Number	
Unthinned	19	206	43 to 418
Previously thinned	16	154	65 to 333
Average stand d.b.h.:		Inches	
Unthinned	19	14.0	8.9 to 19.6
Previously thinned	16	14.6	11.3 to 18.2
Average volume of thinned material, per log:[3]		Cubic feet	
Unthinned	10	20.1	10.4 to 27.5
Previously thinned	9	25.2	19.0 to 33.1

[1] For trees 5 inches d.b.h. and larger.
[2] Before present thinning.
[3] Records of total output and total number of logs per setting were available from only 19 of the 35 study settings, due to work interruptions.

[1] D.b.h. = diameter breast height.
[2] Board-foot volumes throughout this report are in Scribner scale.
[3] Net engine horsepower is used in this report. Drawbar horsepower, another commonly used measure, is usually around 80 percent of net engine horsepower.

The length of most logs cut in the study areas varied from 28 to 40 feet.

All logs included in the study were scaled in both board feet and cubic feet. Cubic-foot log volumes were determined from tables based on small-end diameters and an average taper of 1 inch in 10 feet, or 1 inch in 11 feet, depending on sample taper measurements.

Stopwatch time studies were made of the individual steps in the logging process: Felling, limbing and bucking, tractor travel from the landing, choker setting, skidding, unhooking and decking, and loading. These times and the corresponding production rates were then related to such factors as log volume, skidding distance, volume per turn, and whether or not the stand had been previously thinned. In addition, records were kept of total production and total man-hours and machine-hours for 15 of the study settings.

Objectives of the Study

General objectives of the study were to develop an economic basis for evaluating commercial thinning opportunities and to provide guidelines for development of more efficient logging methods, utilization standards, and plan of operations.

Specific objectives were:

1. To determine production rates for individual steps in the logging operation, as related to operating methods and stand factors, and to compare production rates in previously thinned and unthinned stands of the same stand size or density.
2. To determine production rates for individual logs of different sizes and for different stand characteristics.
3. Using these production rates, to develop representative logging costs for determination of marginal log size under different operating conditions.

[4] The 0.15 probability level was used to define significance of variables. All but two variables were also significant at the 0.10 probability level. These variables were PD in equation 11 and D^2 in equation 13 (p. 7).

Time Study of Individual Logging Operations

Stepwise multiple regression was used to develop, for each step of logging, the functional relationship of time to specified variables. The stepwise technique provides for successively including additional variables, in the order in which they contribute most toward reduction of variance. Variables not making a significant contribution toward reduction of variance were eliminated from the analysis.[4]

Number of observations for each function were as follows:

	Number	Unit
Felling, limbing, bucking	607	Trees
Skidding:		
65-hp. crawler	236	Turns
50-hp. crawler	96	"
60-hp. four-wheel skidder	296	"
Loading	53	Loads

The following symbols are used in the regression equations:

B = Number of bucking cuts after felling
C = Use of extra man (other than tractor operator) for setting or releasing chokers (coded as: no = 0, or yes = 1)
D = Distance in feet
H = D.b.h. in inches
M = Ordinal number of thinning (1 = first thinning, 2 = subsequent thinning)
N = Number of logs per turn
P = Skidding of poles over 48 feet in length (coded as: no = 0, or yes = 1)
S = Hundred cubic feet removed per acre
T_1 = Number of trees per acre, before cut
T_2 = Number of trees per acre, after cut
T_3 = Number of trees cut per acre
V_1 = Volume per turn, in cubic feet

V_2 = Volume per turn, in board feet, Scribner scale

Y = Time per tree, or per turn, for indicated operation, in minutes

Z_1 = Direct cost, in dollars per unit volume

Z_2 = Total cost, in dollars per unit volume

Felling and Bucking Time

Equations, or the mean value, in the case of swamping, for felling and bucking time per tree (figs. 3, 4, and 5) were:

(1) Walking to tree

$$Y = 2.332 - 0.01033T_1 + 0.0000182(T_1)^2 - 0.01235T_3$$

$$R^2 = 0.0829^{**5}$$

Walking time per tree first decreased as number of trees per acre increased, because trees to cut were closer together, then increased after a point where the greater density of trees interfered with travel.

(2) Swamping

Swamping is the clearing away of brush and branches that would interfere with the felling operation. Due to the low coefficient of determination in the regression of swamping time in relation to number of trees per acre, the simple mean of 0.21 minute per tree was used.

(3) Felling

$$Y = 0.5599 + 0.00419H^2$$

$$R^2 = 0.4524^{**}$$

(4) Limbing and bucking

$$Y = 0.7815 + 0.00681H^2 + 1.123B$$

$$R^2 = 0.6676^{**}$$

[5] For this and succeeding regressions, R^2 is the coefficient of determination; ** indicates significance at 0.01 probability level; * indicates significance at the 0.05 probability level.

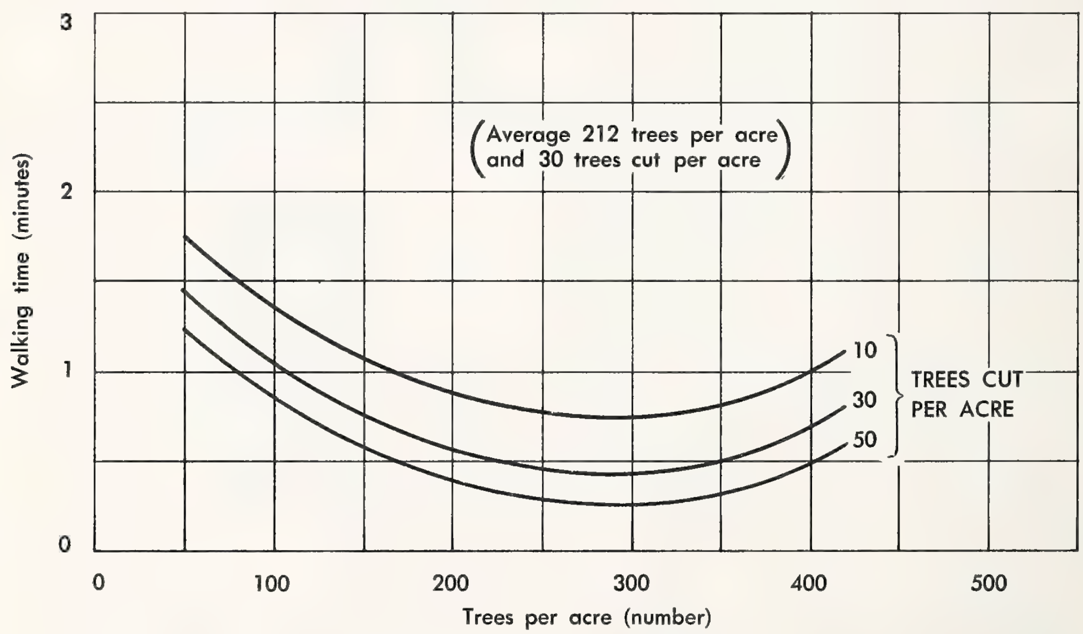

Figure 3.—Walking time per tree, by number of trees per acre and number cut per acre.

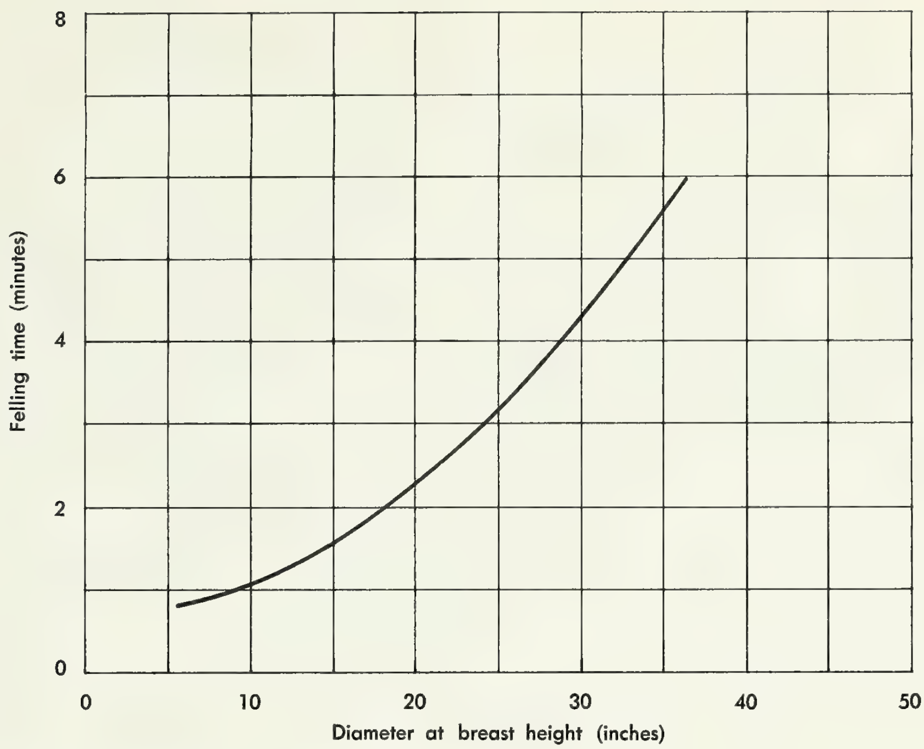

Figure 4.—Felling time per tree, by d.b.h.

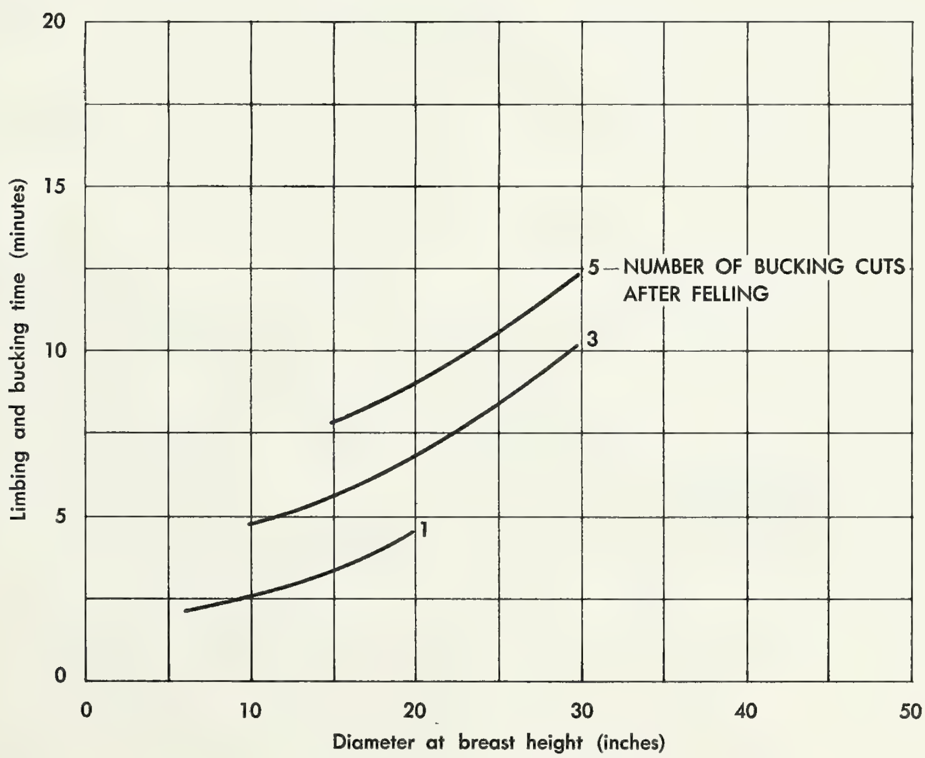

Figure 5.—Limbing and bucking time per tree, by d.b.h. and number of bucking cuts after felling.

Outrun Time Empty

This is the time per turn taken by the tractor as it moves out from the landing to pick up a turn of logs (fig. 6). The four-wheel skidder, although potentially a faster machine, was apparently no faster than the small crawler. This can often be the result when there are no well-defined skidtrails, or when skidtrails are not well developed. The small crawler appeared slightly faster than the larger tractor, probably because its use tended to be assigned to easier ground. This might be the case, for example, when an operator has both a large and a small machine working together.

Outrun times empty were:

(5) 65-hp. crawler
$Y = 1.341 + 0.004136D$
$R^2 = 0.3896^{**}$

(6) 50-hp. crawler
$Y = 1.044 + 0.002866D$
$R^2 = 0.5390^{**}$

(7) 60-hp. four-wheel skidder
$Y = 0.8534 + 0.002951D$
$R^2 = 0.3487^{**}$

Choker-Set Time

Choker-set time (fig. 7) includes positioning the tractor, carrying out chokers, reeling in, and hooking. These times, per turn, were:

(8) 65-hp. crawler
$Y = -1.084 + 2.650N - 0.004775NT_1 - 0.4342NC + 0.00004951(T_1)^2$
$R^2 = 0.4314^{**}$

(9) 50-hp. crawler
$Y = 0.6762 + 1.334N$
$R^2 = 0.4766^{**}$

(10) 60-hp. four-wheel skidder
$Y = 1.230 + 0.6952N + 0.002431NT_1$
$R^2 = 0.3198^{**}$

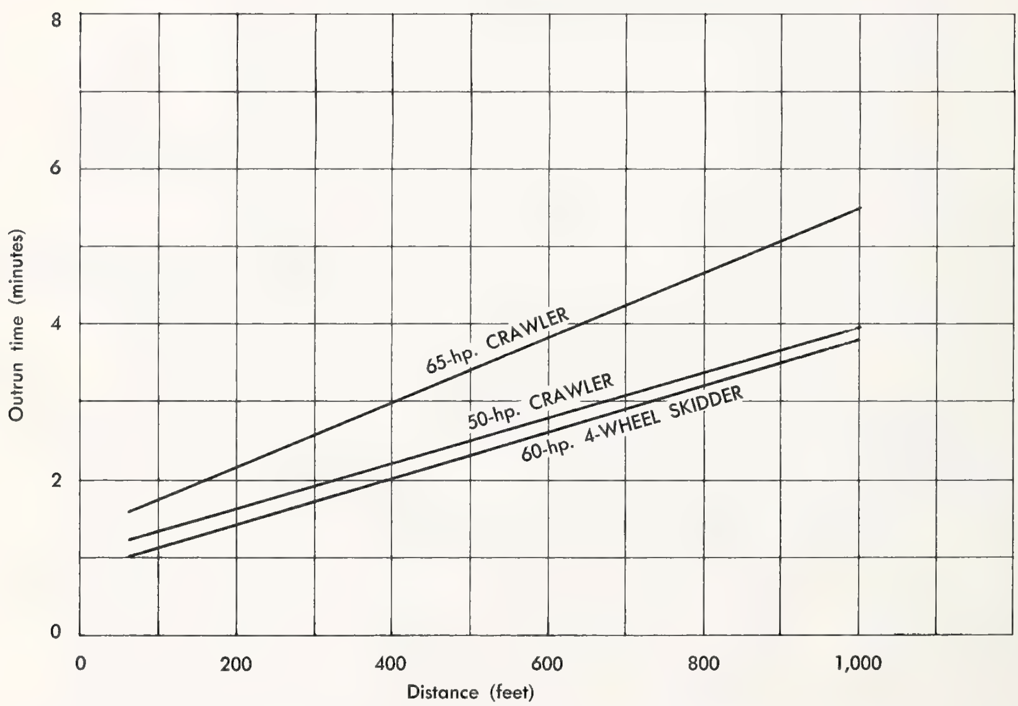

Figure 6.—Outrun time empty per turn, by slope distance and type of skidding machine.

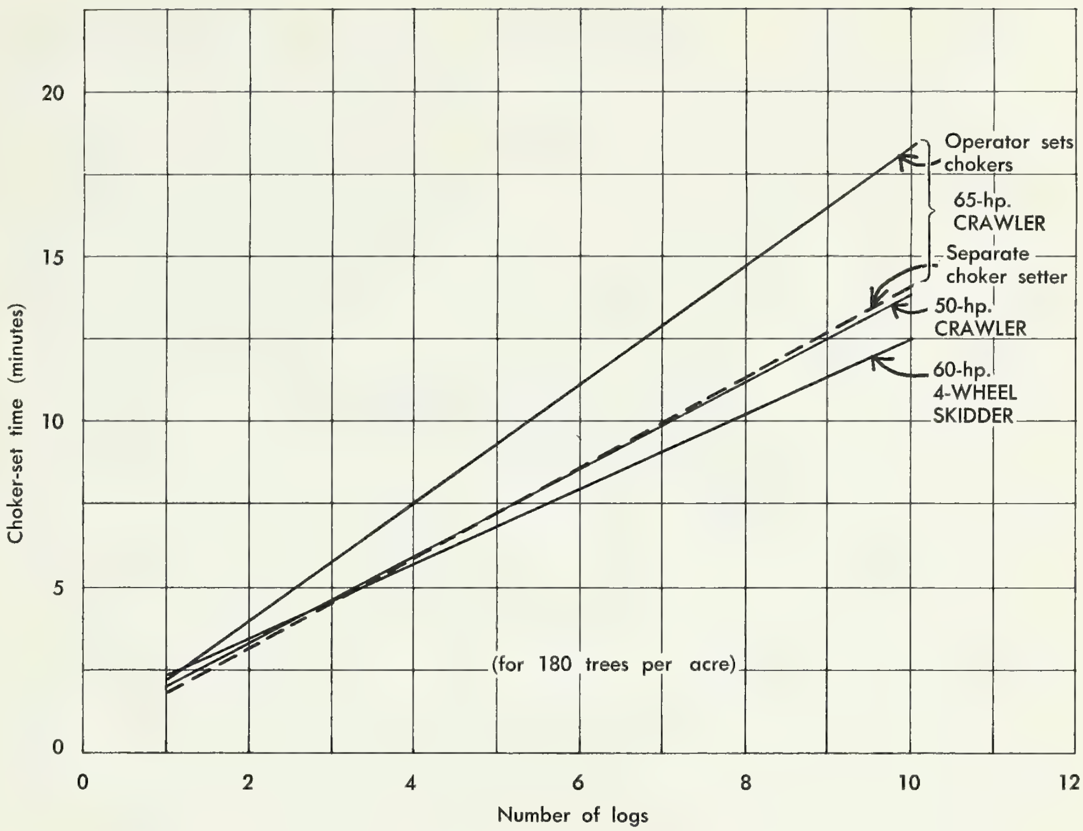

Figure 7.—Choker-set time per turn, by number of logs and type of skidding machine.

Skidding Time

Skidding times per turn (fig. 8) for the three types of skidding equipment were:

(11) 65-hp. crawler

$$Y = 1.220 + 0.005771D + 0.001907PD$$
$$R^2 = 0.3921^{**}$$

(12) 50-hp. crawler, cubic feet

$$Y = 1.909 + 0.005197D + 0.03666V_1 - 0.0001250(V_1)^2 + 0.003237T_2$$
$$R^2 = 0.7408^{**}$$

(13) 60-hp. four-wheel skidder, cubic feet

$$Y = -0.08486 + 0.003425D - 0.000001057D^2 + 0.009834V_1 + 0.002964T_2$$
$$R^2 = 0.3466^{**}$$

(14) 50-hp. crawler, board feet

$$Y = -0.9238 + 0.005162D + 0.002705V_2 + 0.003279T_2$$
$$R^2 = 0.7430^{**}$$

(15) 60-hp. four-wheel skidder, board feet

$$Y = 0.04807 + 0.003502D \div 0.000001096D^2 + 0.001777V_2 + 0.003079T_2$$
$$R^2 = 0.3483^{**}$$

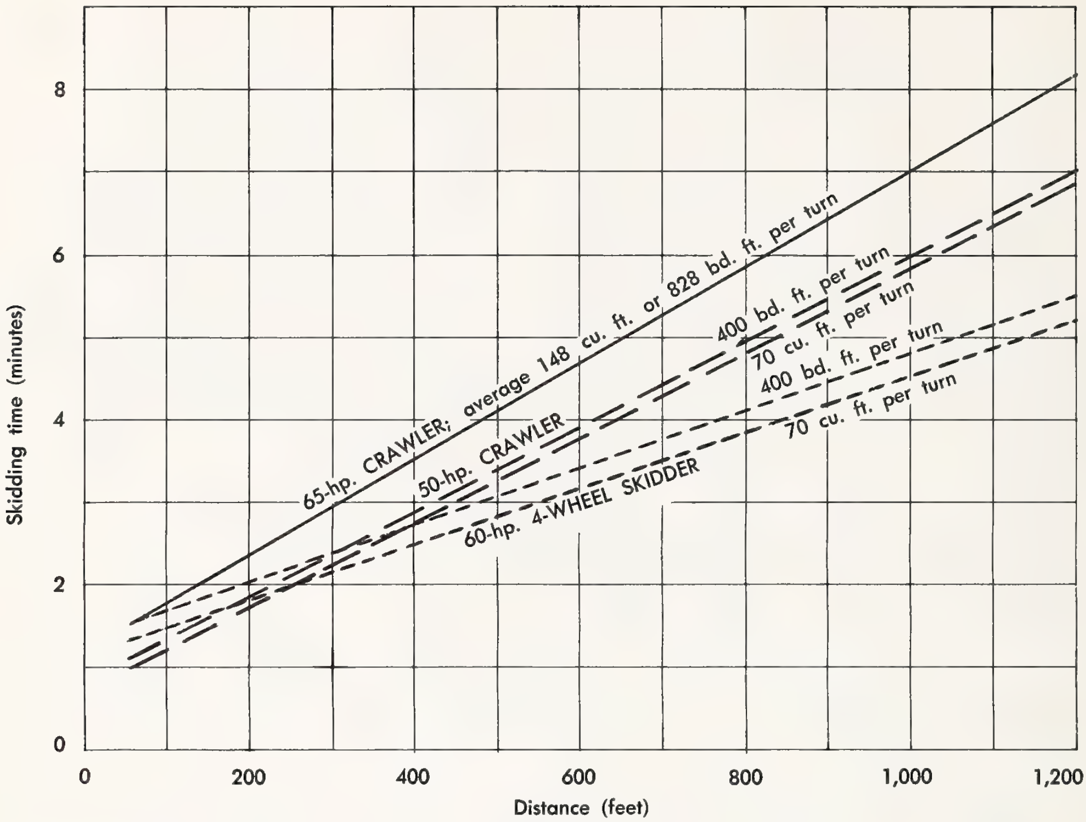

Figure 8.—Skidding time per turn, by slope distance and type of skidding machine.

Unhooking and Decking Time

Unhooking and decking time, per turn (fig. 9), were measured together as a single item, as follows:

(16) 65-hp. crawler, cubic feet

$$Y = 0.5228 + 0.009761V_1 + 0.04287N^2 = 0.2094CN$$

$$R^2 = 0.3590^{**}$$

(17) 50-hp. crawler

$$Y = 0.7884 + 0.3914N$$

$$R^2 = 0.5919^{**}$$

(18) 60-hp. four-wheel skidder

$$Y = 1.054 + 0.2627N$$

$$R^2 = 0.1091^{**}$$

(19) 65-hp. crawler, board feet

$$Y = 0.6392 + 0.001421V_2 + 0.0485N^2 - 0.1838CN$$

$$R^2 = 0.3428^{**}$$

Unhooking time for the 65-hp. crawler was significantly less with a separate man to release the chokers (fig. 10). The difference was greater with a larger number of logs because then the chokers were more apt to bind and require "shaking" of the turn by the tractor operator.

Extra time for unhooking and decking poles, which generally were placed in a separate pile parallel to the truck road, averaged 0.082 minute per cubic foot, or 0.017 minute per board foot (fig. 11). This was an average for all three types of skidding machine.

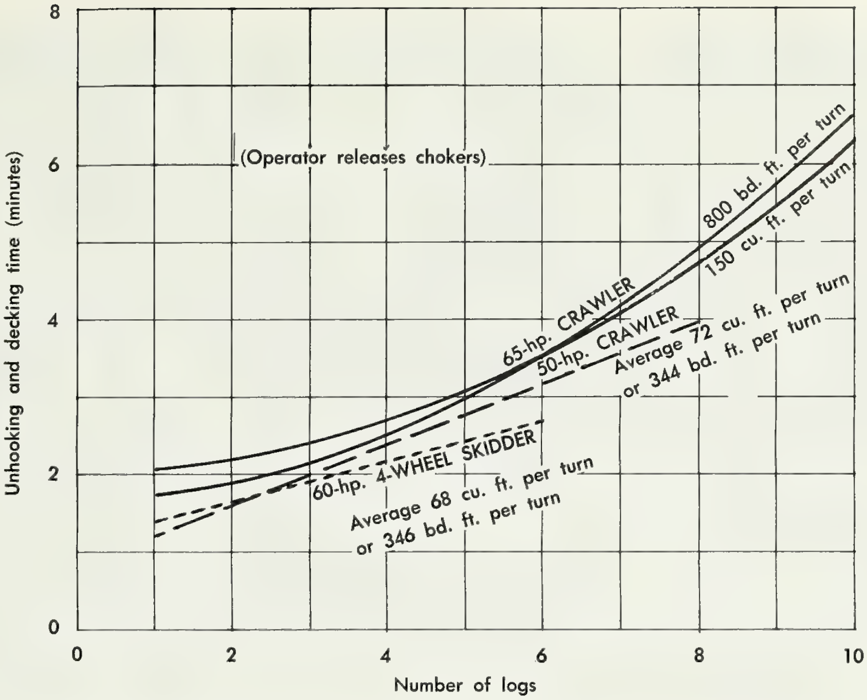

Figure 9.—Unhooking and decking time per turn, by number of logs and type of skidding machine.

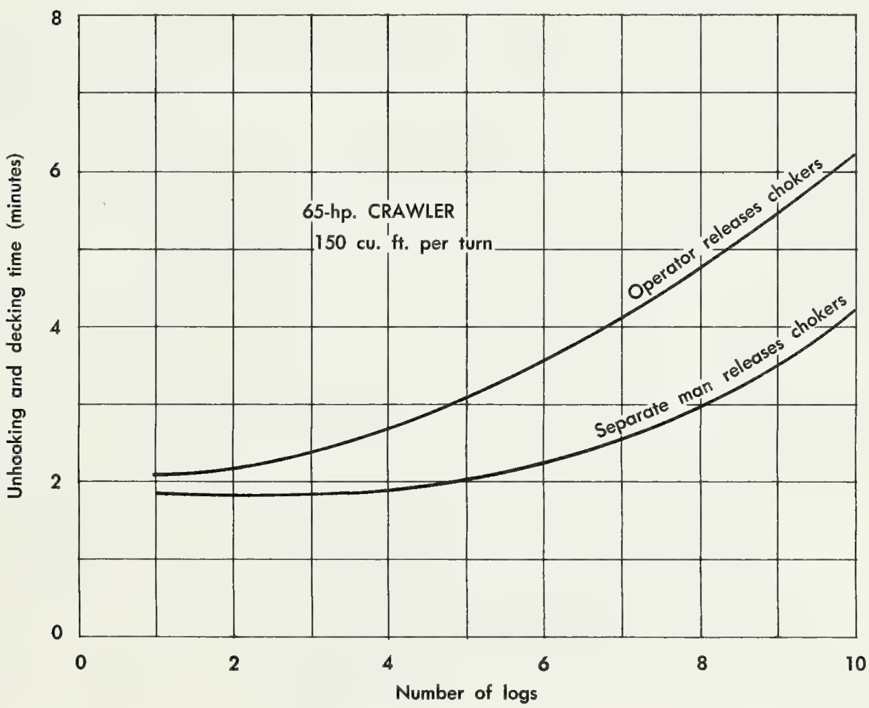

Figure 10.—Unhooking and decking time per turn, by number of logs, showing difference with separate man to release chokers.

Figure 11.—Poles and piling are decked alongside the road.

Loading

Loading may be carried out each day along with skidding or, on other operations, logs may be decked for one or more settings and loaded later in a continuous operation (figs. 12 and 13).

Loading by industrial landowners was with modern, high-speed equipment having automatic tongs and dipper-stick boom arrangement.

Contractors generally had slower equipment and used tongs or grapple. All but one contractor used a separate, shovel-type loader, either track-mounted or on rubber tires. The one exception used a crawler-type forklift loader.

Loading times were recorded in two parts: fixed time per load for positioning, coupling, and binding off the trailer, and direct loading time. Averages were calculated as follows:

	Fixed time per load	Direct loading time per log
	— — — (Minutes)	— — —
Long logs (24-48 feet):		
Industrial landowners	11.4	0.60
Contractors	16.3	1.33
8-foot wood	13.8	.32

Figure 12.—Some firms delay loading until skidding on a given setting or spur is completed, then load and haul with large mobile equipment.

Figure 13.—Loading two or three logs at once saves time with small logs.

Delay Time Factors

Besides the working times developed in all of the foregoing equations or average times, delay times must also be considered. The following factors for **operating delays** were developed. For simplification these are expressed as proportional to nondelay time for the various operations.

Operation	Delay time factor
Felling, limbing, and bucking	0.596
Skidding, complete cycle	0.385
Loading	0.123

Breakdown and other types of **nonoperating delay,** such as moving to new settings, shutdown for weather, or for major repairs, were taken into account in estimating the number of working days per year. Basis for classification of delays is discussed by Matthews (1942, pp. 73-90) and Lussier(1961, pp. 85-87).

Comparison of First and Subsequent Thinnings

Up to this point, the concern has been with time and volume of individual turns, trees, or logs. On such a basis, no significant difference was found in the time for any observed element of the logging cycle, as between first and subsequent thinnings. However, there was a significant difference in cost per hundred cubic feet when cost was related to **total** time and output per setting.[6] That is, the aggregate felling and skidding costs were $3.52 less per hundred cubic feet for the previously thinned settings than on the settings which had never been thinned before. The regression equation (fig. 14) of cost per hundred cubic feet was:

[6] Data on total time and output were collected on 15 of the study settings. In the comparison of first and subsequent thinnings, the total time included the time to lay out and clear skidtrails and, in some cases, to develop or enlarge landings. The aggregate felling and skidding cost includes the cost of the crew and equipment for the total time they were on the setting.

$$(20)\quad Z_1 = 13.80 + 9.588\left(\frac{1}{S}\right) - 3.520M$$

$$R^2 = 0.5830^*$$

Both the factors, S (hundred cubic feet removed per acre) and M (ordinal number of thinning (coded as 1 or 2), were significant at the 0.05 probability level.

A corresponding regression analysis of aggregate felling and skidding cost per thousand board feet, related to thousand board feet removed per acre, and ordinal number of thinning, showed neither element to be statistically significant. In small-diameter timber, there is considerable variability in the ratio of board-foot measure to solid contents of the tree or log. Thus, it is possible to have significant cost differences on a cubic-foot basis, when related to volume cut per acre, but not on a board-foot basis.

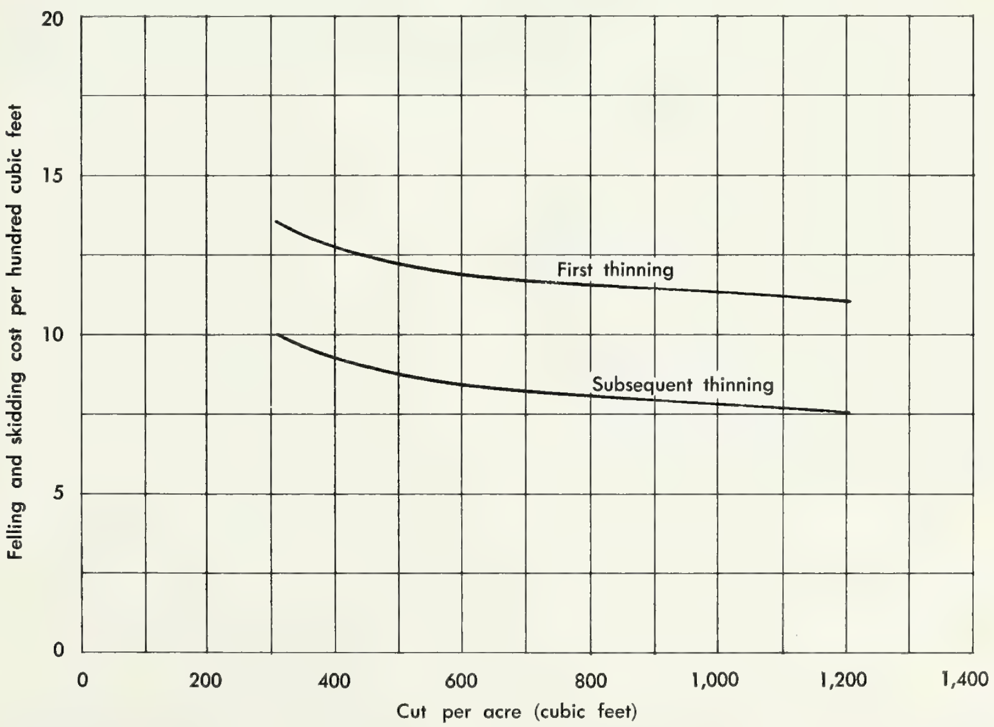

Figure 14.—Aggregate felling and skidding cost per hundred cubic feet for first and subsequent thinnings, related to cut per acre.

Direct Costs of the Skidding Cycle

Direct costs are those incurred when a specific action is performed, such as skidding a turn of logs. These are to be distinguished from fixed costs, or overhead costs, which are incurred in a fixed manner, such as per year or per setting, and which are not related directly to any specific action.

For example, the direct cost of an individual turn of logs includes the cost of labor and equipment time necessary to bring in that turn of logs. Excluded are fixed costs of supervision, cruising, scaling, office overhead, roadbuilding, road maintenance, slash disposal, fire protection, and engineering. Also excluded are costs of moving in and landing construction. These fixed costs must be borne by the operation as a whole.

The direct costs incurred in the skidding cycle are those associated with skidding-machine outrun, choker setting, skidding, unhooking, and decking. A comparison of direct skidding-cycle costs, based on log volume, shows sharply rising costs for low-volume logs (figs. 15 and 16). The same effect is evident for low-volume turns (figs. 17 and 18).

The concept of direct costs, by log size or turn size, avoids the use of an average cost for all sizes and focuses attention on the variation in these costs.

Note that the hourly machine rates used in calculating equipment costs cover not only fuel and labor but also the full hourly machine rate for equipment, including such things as depreciation and related items of interest, taxes, and insurance.[7] See appendix tables 6 to 15.

Direct costs, as calculated here, also include the cost of a share of delay time, because the small operating delays observed occurred so frequently that the decision was made to treat them as a part of operating time. These delays usually cannot be avoided and are just as apt to occur at one time as another. In some situations, a separation of delay and operating times might be appropriate.[8]

Skidding times and costs per log, as contrasted to per turn, were derived by assuming turns of uniform log size and assigning each log an equal share of the turn time and cost.

Skidding costs for small logs were relatively high because they reflect (1) the extra time for choking and unhooking a larger number of logs; (2) the fact that, with a large number of small logs and a maximum of 10 chokers, it was often not possible to assemble a full load for the capacity of the tractor. Skidding costs **per turn** were calculated on the basis of six logs per turn, for all turn volumes.

[7] For further discussion of this point, see Adams (1965), pp. 2 and 36.

[8] For example, the extra cost of "bonus logs," discussed later in this report, is calculated without inclusion of any delay times.

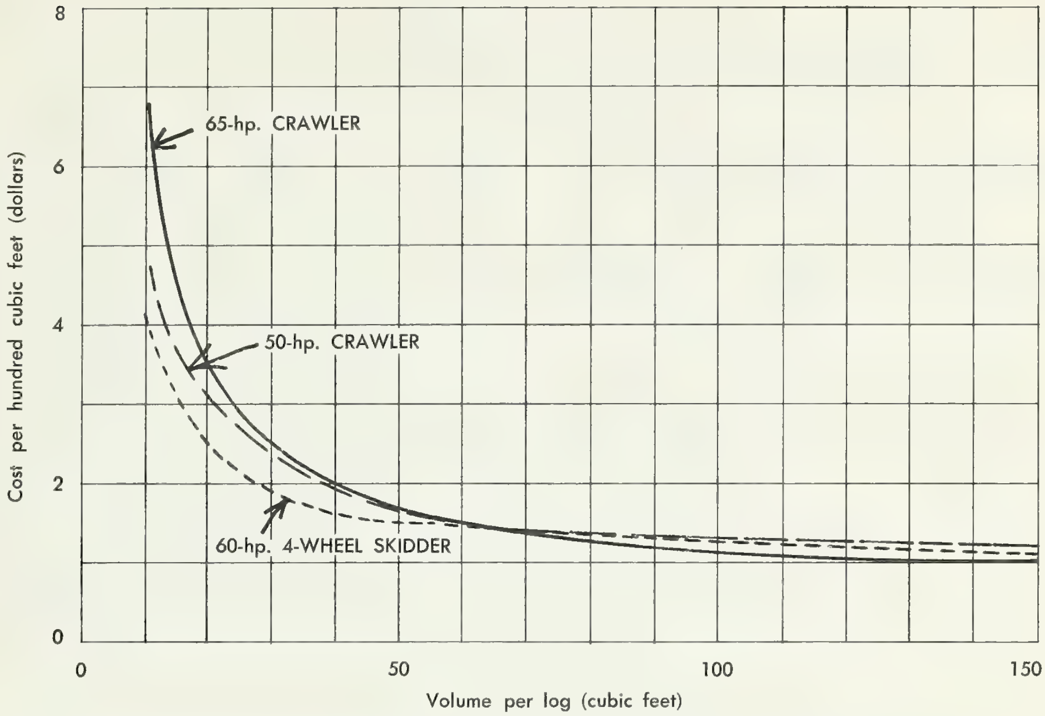

Figure 15.—Direct skidding-cycle cost per hundred cubic feet (for distance = 400 feet), based on log volume, by type of skidding machine.

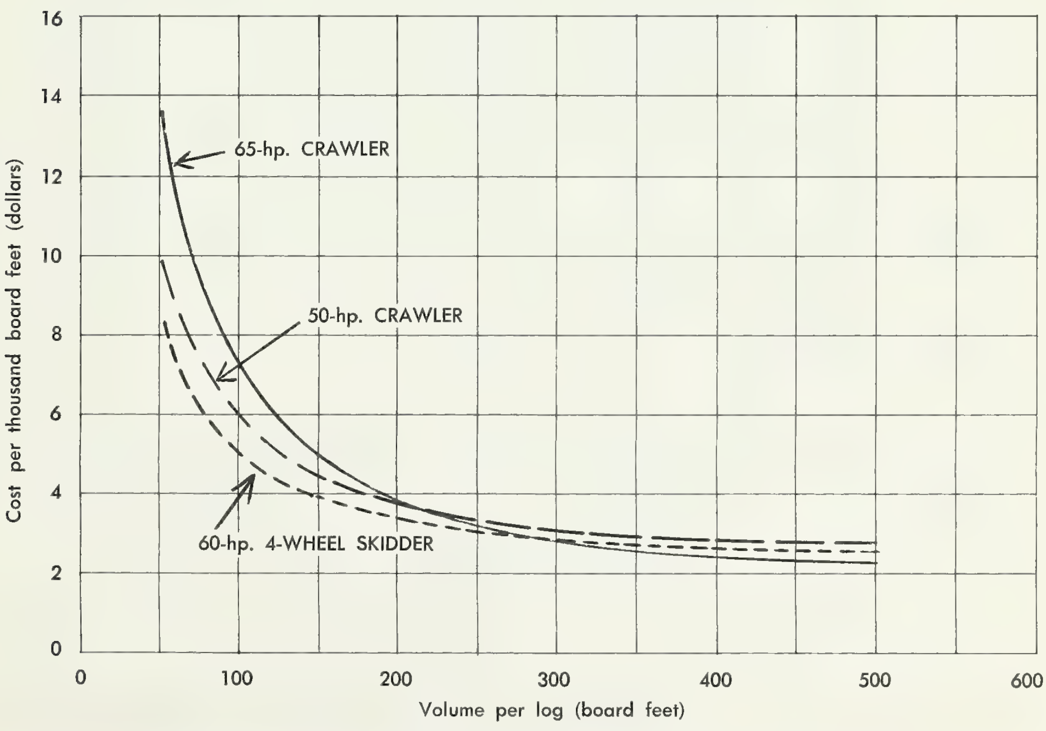

Figure 16.—Direct skidding-cycle cost per thousand board feet (for distance = 400 feet), based on log volume by type of skidding machine.

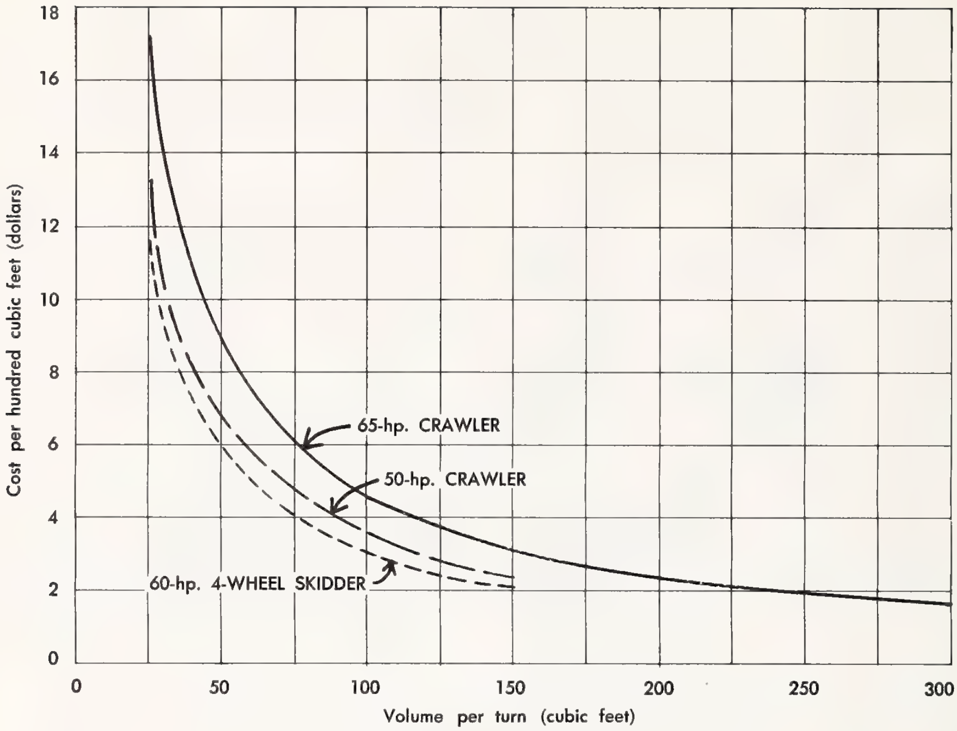

Figure 17.—Direct skidding-cycle cost per hundred cubic feet (for **distance** = 400 feet), based on turn volume, by type of skidding machine.

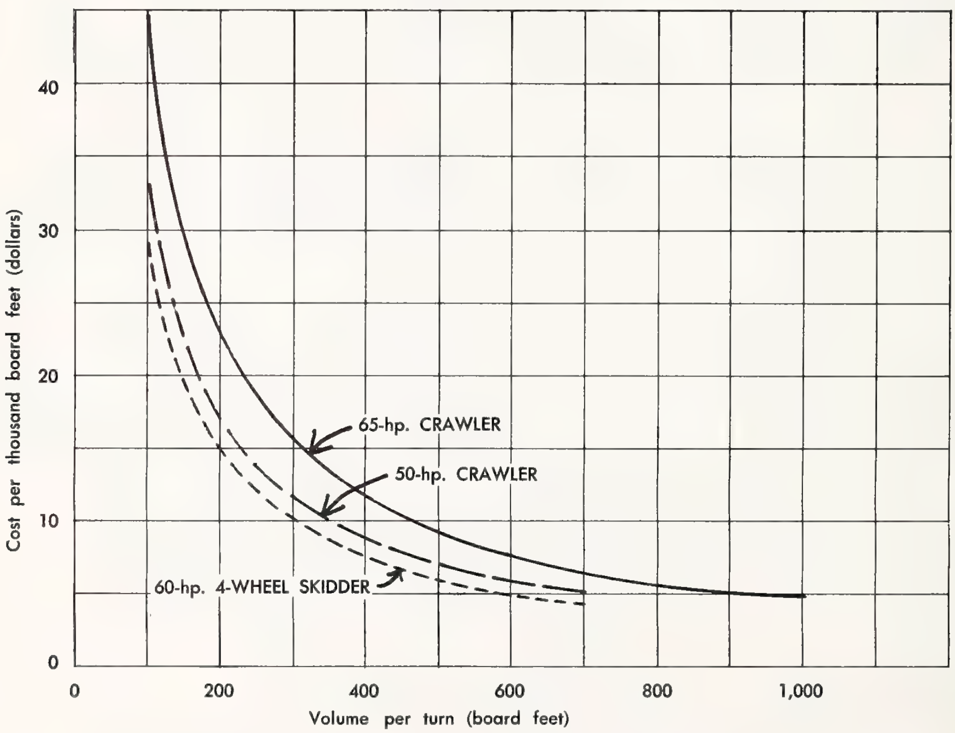

Figure 18.—Direct skidding-cycle cost per thousand board feet (for distance = 400 feet), based on turn volume, by type of skidding machine.

Total Direct Logging Costs

In addition to direct costs of the skidding cycle, the total direct logging costs include limbing and bucking, loading, and hauling (tables 2, 3, and 4; figs. 19 and 20).[9]

These are shown by log volume, for representative skidding distance of 400 feet and hauling distance of 30 miles. Times and costs for other skidding distances are shown in the appendix, tables 16 to 24.

Limbing and bucking costs were determined from regression times relating to d.b.h. and number of bucking cuts, together with machine rate for one-man powersaw and operator. Cubic-foot and board-foot volumes associated with these diameters were divided into cost per tree to give cost per unit volume.[10]

Loading costs were determined from average loading time and cost per log divided by log volume.

Representative hauling costs, for hauling distances up to 70 miles, are developed in the appendix, tables 25 to 28.

Table 2.—Total direct logging costs per unit volume in Douglas-fir thinning operations, by function, 65-hp. crawler tractor, 1965[1]

Volume per log	Number of logs per turn	Function				
		Limbing and bucking	Skidding (400 feet)	Loading[2]	Hauling (30 miles)	Total
Cubic feet:		Dollars per 100 cubic feet				
5	10	6.50	13.20	4.00	6.01	29.71
10	10	3.50	6.71	2.00	6.01	18.22
25	10	1.80	2.81	.80	5.60	11.01
50	6	1.00	1.67	.40	5.44	8.51
100	3	.75	1.20	.20	5.43	7.58
150	2	.70	1.10	.13	5.38	7.31
Board feet:[3]		Dollars per M board feet				
20	10	13.60	33.55	10.00	15.01	72.16
50	10	8.10	13.60	4.00	14.12	39.82
100	10	4.20	6.96	2.00	12.28	25.44
200	7.5	2.40	3.81	1.00	10.79	18.00
500	3	2.30	2.31	.40	8.57	13.58

[1] Horsepower is net engine horsepower. Costs were calculated on the assumption of uniform log size per turn.
[2] Full-time company loading.
[3] Scribner rule.

[9] Walking, swamping, and felling costs are excluded here, on the assumption that the tree is already felled, for at least one merchantable log. The question is, "What is the cost of an additional log?"

[10] This is an approximation only; it was not practical to time and measure or scale each log separately during the felling operation.

Table 3.—Total direct logging costs per unit volume in Douglas-fir thinning operations, by function, 50-hp. crawler tractor, 1965[1]

Volume per log	Number of logs per turn	Function				
		Limbing and bucking	Skidding (400 feet)	Loading[2]	Hauling (30 miles)	Total
Cubic feet:		Dollars per 100 cubic feet				
5	10	6.50	9.42	8.00	6.01	29.93
10	10	3.50	4.92	4.00	6.01	18.43
25	6	1.80	2.37	1.60	5.60	11.37
50	3	1.00	1.67	.80	5.44	8.91
100	1.5	.75	1.32	.40	5.43	7.90
150	1	.70	1.20	.26	5.38	7.54
Board feet:[3]		Dollars per M board feet				
20	10	13.60	23.45	20.00	15.01	72.06
50	10	8.10	9.76	8.00	14.12	39.98
100	7	4.20	5.60	4.00	12.28	26.08
200	3.5	2.40	3.84	2.00	10.79	19.03
500	1.4	2.30	2.71	.80	8.57	14.38

[1] Horsepower is net engine horsepower. Costs were calculated on the assumption of uniform log size per turn.
[2] Part-time contractor loading.
[3] Scribner rule.

Table 4.—Total direct logging costs per unit volume in Douglas-fir thinning operations, by function, 60-hp. four-wheel skidder, 1965[1]

Volume per log	Number of logs per turn	Function				
		Limbing and bucking	Skidding (400 feet)	Loading[2]	Hauling (30 miles)	Total
Cubic feet:		Dollars per 100 cubic feet				
5	10	6.50	8.10	8.00	6.01	28.61
10	10	3.50	4.14	4.00	6.01	17.65
25	6	1.80	2.09	1.60	5.60	11.09
50	3	1.00	1.54	.80	5.44	8.78
100	1.5	.75	1.26	.40	5.43	7.84
150	1	.70	1.17	.26	5.38	7.51
Board feet:[3]		Dollars per M board feet				
20	10	13.60	20.25	20.00	15.01	68.86
50	10	8.10	8.28	8.00	14.12	38.50
100	7	4.20	4.80	4.00	12.28	25.28
200	3.5	2.40	3.41	2.00	10.79	18.60
500	1.4	2.30	2.64	.80	8.57	14.31

[1] Horsepower is net engine horsepower. Costs were calculated on the assumption of uniform log size per turn.
[2] Part-time contractor loading.
[3] Scribner rule.

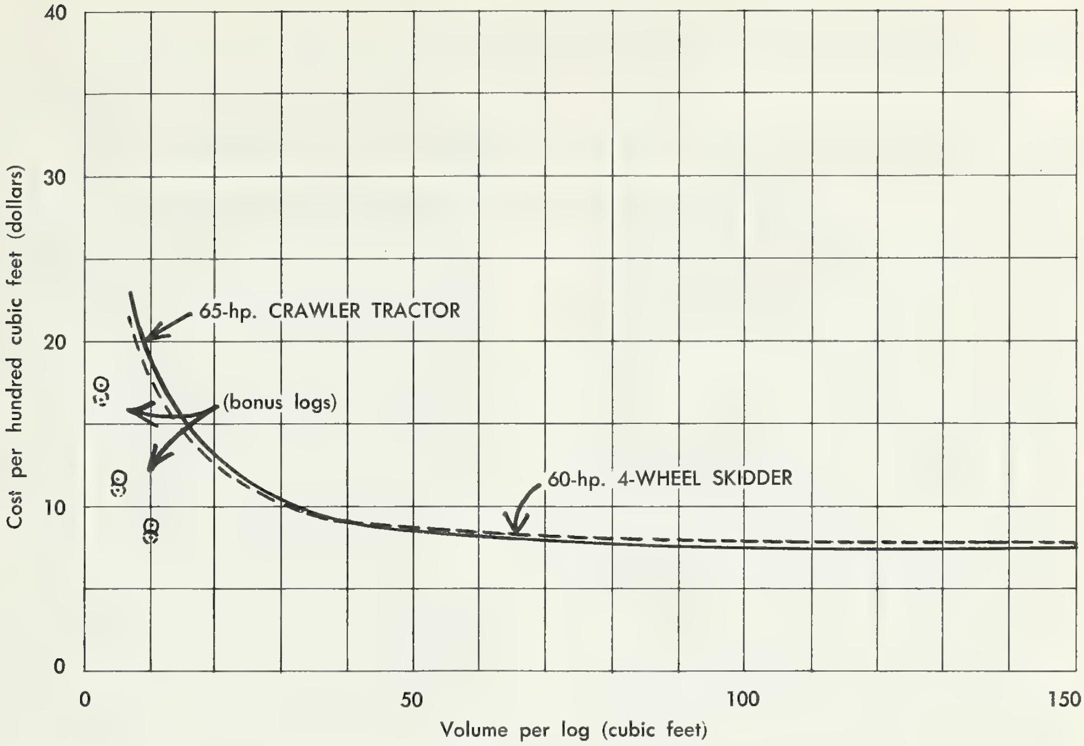

Figure 19.—Total direct logging cost per hundred cubic feet, including limbing and bucking, skidding (400 feet), loading, and hauling 30 miles, by type of skidding machine.

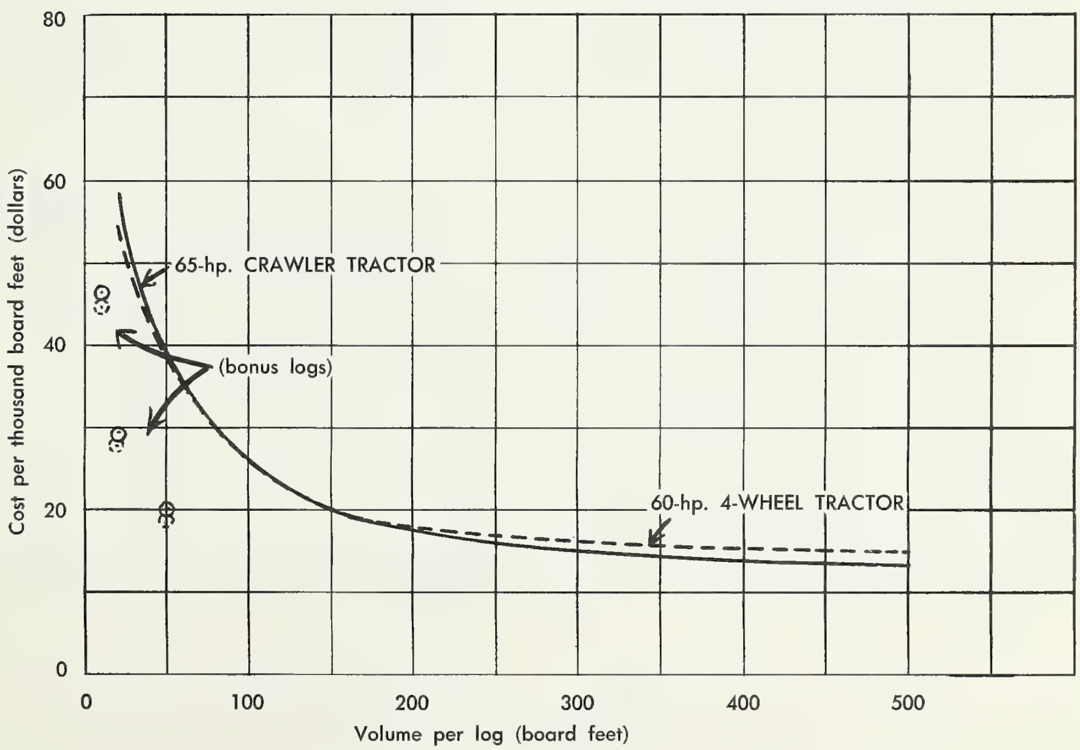

Figure 20.—Total direct logging cost per thousand board feet, including limbing and bucking, skidding (400 feet), loading, and hauling 30 miles, by type of skidding machine.

The Marginal Log and Tree

The marginal log is one that just pays its way, or whose value is just equal to its direct costs. For example, if the pond value for small logs is $50 per thousand board feet and logging costs are those shown in figure 20, then a 30-board-foot log is the marginal log. Its direct cost, to the log pond, just equals its pond value. Any smaller volume log costs more per thousand board feet, and any larger volume will cost less.

Each logging manager can apply his own hourly cost rates to the functional times developed earlier in this report, or to his own times, to determine his own curve of total direct costs per unit volume of production. The intersection of this cost curve with his log value curve determines the marginal log size.

The marginal **tree,** as distinguished from the marginal log, will contain at least one log whose value is just equal to its direct costs, including, in this case, the cost of the felling operation in addition to the other direct logging costs. The extra cost of felling, including walking to the tree and swamping, for a cut of 30 trees per acre and a stand of 200 trees per acre, is estimated from the regression times as follows:

Tree volume	Felling cost
	(Dollars per 100 cu. ft.)
Cubic feet:	
5	4.50
10	2.30
25	1.00
50	.60
100	.50
150	.45
	(Dollars per M bd. ft.)
Board feet, Scribner scale:	
20	9.30
50	5.60
100	3.60
200	1.55
500	1.10

Bonus Logs a Special Case

Bonus logs are considered here to be extra logs that are skidded with an otherwise full or nearly full turn, where larger logs are not easily available to complete the turn. That is, they can go free in some logging steps. They need not cover overhead or fixed costs, not even the fixed cost per tree of felling nor the fixed costs per turn of tractor skidding. Bonus logs need cover only their direct cost for the extra time of limbing and bucking, choking, unhooking, and loading. As used here, a full turn is one which approximates the load capacity of the skidding machine.

Of course, any return over a log's direct costs is available to cover at least part of the fixed costs. That is, the very small logs add to total volume and thus lower the fixed cost per thousand board feet, but if they do not even cover their own direct costs then they will add more to total cost per thousand board feet than they reduce by lowering average fixed costs.

Direct costs per log for bonus logs, from limbing and bucking through loading, are derived as follows:

	Direct cost per log		
	65-hp. crawler	50-hp. crawler	60-hp. four-wheel skidder
	— — —	(Dollars)	— — —
Limbing and bucking, 0.6 min. x $0.0927	0.06	0.06	0.06
Choker setting, unhooking, and decking:			
0.6 min. x $0.161	.10	--	--
0.6 min. x $0.147	--	.09	--
0.6 min. x $0.138	--	--	.08
Loading, 0.5 min. x $0.266	.13	.13	.13
	.29	.28	.27

In most situations, the cost of bonus logs should also include the cost of hauling.[11]

[11] A case might be made for overlooking the time cost of truck and driver during loading of bonus logs—and even the main hauling cost itself—if bonus logs are used to top off a load that could not take another larger log.

Direct cost per log, multiplied by number of logs per hundred cubic feet or per thousand board feet, gives direct cost per unit volume (table 5, figs. 19 and 20). For bonus logs, these costs are figured without any delays and are shown in figures 19 and 20 by single points enclosed in a solid- or broken-line circle.

Bringing in bonus logs down to 2.5 cubic feet or 10 board feet in volume may be feasible under the conditions shown. However, complete turns of such small logs, or utilization of any sizable amount of such logs, would not permit their qualifying as bonus logs, and the cost of tractor skidding time could not be ignored.

Stumpage as a Direct Cost

If the operator pays a direct stumpage charge based on the log scale of each truckload taken out, then this stumpage charge is a part of the direct cost of each log. This tends to discourage removal of small material. If the timber is purchased on a lump-sum or fixed-sum basis, there is, of course, no direct stumpage charge for a given log, and operators have an incentive to remove everything that will cover its direct logging cost. This is an important feature of lump-sum or tree-measurement sales.

Income Tax Effects

Wood from company-owned lands can often qualify for capital gain tax treatment which results in reduced Federal income tax. The effect is to increase the before-tax cost of the marginal log, or to lower the size of the marginal log. This is because a capital gain in the value of the timber is taxed at 25 percent instead of the normal 48-percent Federal corporate income tax. This represents a saving of 23 percent.[12]

For example, if purchased wood costs $30 per hundred cubic feet delivered at the mill, and if the firm's own wood may be given a fair market value of $15 per hundred cubic feet and a depletion rate of $5 per hundred cubic feet, then the equivalent value of company wood may be calculated as $34.42, shown as follows:

After-tax logging cost of company wood equals after-tax delivered cost of purchased wood plus tax reduction due to capital gain. Thus, where x is the before-tax logging cost of company wood,

$$\begin{aligned} x - 0.48x = \$30 &- 0.48\ (\$30) \\ &+ 0.48\ (\$15 - \$5) \\ &- 0.25\ (\$15 - \$5) \end{aligned}$$

Table 5.—Direct cost per unit volume of bonus logs, with various types of equipment and 30-mile haul[1]

Logs		65-hp. crawler[2]			50-hp. crawler[2]			60-hp. four-wheel skidder[2]		
Size	Number per unit	Logging	Hauling	Total	Logging	Hauling	Total	Logging	Hauling	Total
Cu. ft.	100 cu. ft.	Dollars per 100 cubic feet								
2.5	40	11.60	6.01	17.61	11.20	6.01	17.21	10.80	6.01	16.81
5	20	5.80	6.01	11.81	5.60	6.01	11.61	5.40	6.01	11.41
10	10	2.90	6.01	8.91	2.80	6.01	8.81	2.70	6.01	8.71
Bd. ft.	M bd. ft.	Dollars per M board feet								
10	100	29.00	18.20	47.20	28.00	18.20	46.20	27.00	18.20	45.20
20	50	14.50	15.01	29.51	14.00	15.01	29.01	13.50	15.01	28.51
50	20	5.80	14.12	19.92	5.60	14.12	19.72	5.40	14.12	19.52

[1] Bonus logs are considered here to be extra logs that go in with an otherwise full or nearly full turn, where larger logs are not easily available to complete the turn.
[2] Horsepower shown refers to net engine horsepower.

[12] Other timber owners can also qualify for capital gain tax treatment under certain conditions. See Williams (1965).

or,

$$\begin{aligned} 0.52x &= 0.52\ (\$30) + 0.23\ (\$15 - \$5) \\ &= \$15.60 + \$2.30 \\ &= \$17.90 \\ x &= \$34.42 \end{aligned}$$

That is, the firm can afford to stand an after-tax logging cost for company wood equal to the sum of (1) the after-tax cost of an equal amount of purchased wood and (2) the difference between capital gains tax at 25 percent and corporate income tax of 48 percent on the amount of the firm's receipts shown as a capital gain instead of as ordinary income.

To state the same thing in terms of marginal log analysis, the firm's logging cost of $34.42 per hundred cubic feet represents an after-tax cost of $30. If a log's value is also $30 per hundred cubic feet, it is a marginal log. Thus, the firm can afford to spend up to $34.42 per hundred cubic feet in direct logging costs for logs whose value to the firm is $30. Any lower cost adds to the firm's revenue, and any larger cost represents a loss for that size of material.

Other Considerations

The above analysis of the marginal log and marginal tree has considered only the value of the log, at the mill or other delivery point. Other values or benefits may also be generated by thinning, or by utilization of a greater portion of trees that are cut. These other benefits might include improved opportunity for growth and development of the residual stand, reduction of fire or other hazard, greater flexibility of operations, or a cleaner looking forest. If the value of these benefits were included in the analysis of the marginal log and tree, it might justify greater costs and, in effect, lower the size of the marginal tree and log.

A Total Cost Estimating Equation

So far, attention has been focused on direct costs or marginal costs. The logging manager may also be interested in total logging costs, which would include road construction, supervision and other elements of logging burden or overhead,[13] administrative overhead, marking, and scaling.

Using Z_2 = total cost, k = supervision and overhead as a constant proportion of average direct costs Z_1; F = fixed cost of moving in and landing construction; Q = road construction cost; and S = marking and scaling cost; all per unit volume, the resulting total cost equation then becomes:

$$(21)\quad Z_2 = Z_1 + kZ_1 + F + Q + S$$

Cost of supervision is sometimes estimated as 10 percent of wage costs; overhead, as 10 percent of all direct costs (U.S. Bureau of Land Management 1965). This comes to approximately 15 percent of direct costs, or k = 1.15.

Fixed costs, F, of moving in and of landing construction are estimated as approximately $200 per 15-acre setting; with a cut of 6,000 board feet per acre, this would be $2.22 per thousand board feet, or approximately $1.23 per hundred cubic feet. Cost of additional landings in the same area would be cheaper and would reduce the overall cost per unit volume.

Road construction cost, Q, can have wide variation, depending on the circumstances. Often an annual carrying charge, rather than the actual road cost, may be estimated. This follows from the principle that the actual road cost will be borne by the final harvest, and the annual carrying charge might be calculated as 6 percent of the undepreciated road balance. Even this annual carrying charge may be as much as $1 or $2 per hundred cubic feet.

[13] Logging burden includes such items as fire protection, slash disposal, snag felling, and road maintenance.

In many situations, however, no new roads at all will be required. As a matter of fact, with the growing accumulation of the region's access roads over the last 30 years, there is a sizable proportion of total area already accessible.

Marking and scaling costs, S, will also vary widely, depending on methods and degree of professional effort devoted to these functions. Some forest managers have had good results with marking done by skilled forest technicians, under guidelines and supervision by professional foresters. With adequate training and control, such a method holds promise for a substantial reduction in marking costs, compared with having all marking done by professional foresters. Scaling costs can be reduced or eliminated by use of some method of weight scaling, or by lump-sum or tree-measurement sales.

The direct logging costs developed earlier in this report will help indicate which logs or trees will be profitable once an operation is underway. The total cost equation will serve as a framework for analysis of the total cost per unit volume for the operation as a whole. The total cost analysis is useful to help make the decision of whether or not to undertake a given operation in the first place.

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Appendix

Table 6.—Machine rate, 65-hp. crawler tractor with arch, based on 8-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
	— — — — —	Dollars	— — — — —
List price, including freight[3]	20,800.00	--	--
Rubber-tired arch, used	750.00	--	--
Residual value, 10 percent of initial price	2,155.00	--	--
Amount to be depreciated	19,395.00	--	--
Average investment for imputed interest[4] $\frac{I+R}{2} = \frac{\$23,705}{2}$	11,852.50	--	--
Average investment for insurance and taxes[4] $\frac{I+R+D}{2} = \frac{\$27,584}{2}$	13,792.00	--	--
Fixed costs:			
Depreciation, 5 years $\frac{\$19,395}{5}$	--	3,879.00	--
Imputed interest, 6 percent of average investment	--	711.15	--
Insurance, 1 percent of average investment	--	137.92	--
Taxes, 2 percent of average investment	--	275.84	--
Repairs and maintenance, 90 percent of depreciation	--	3,491.10	--
Imputed interest on initial choker investment, 6 percent x $10.50 x 10	--	6.30	--
	--	8,501.31	4.72
Variable costs:			
Fuel, 3.15 gallons per hour x $0.16	--	--	.50
Engine oil, 0.05 gallon per hour x $0.65	--	--	.03
Lubrication, 0.1 lb. per hour x $0.15	--	--	.02
Filters, estimated	--	--	.01
Wire rope: 3/4-inch drum line, 65 feet x $0.456 = $29.64 + $4.65 hardware = $34.29 every 6 months	--	68.58	--
1/2-inch chokers, 6 per year at $6.70	--	40.20	--
Replacement hooks, 3 per year at $3.80	--	11.40	--
	--	120.18	.07
Labor, at $3.075 per hour x 1.25 payroll overhead	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	9.68
Total per minute	0.161	--	--

[1] Horsepower is net engine horsepower.
[2] At 225 days x 8 hours = 1,800 hours per year.
[3] Includes blade, canopy, and winch.
[4] I = initial cost; R = residual value; D = depreciation.

Table 7.—Machine rate, 65-hp. crawler tractor with arch, based on 6.3-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
	— — — — —	Dollars	— — — — —
Fixed costs, less repairs and maintenance[3]	--	5,010.21	--
Repairs and maintenance, $\frac{6.3}{8}$ or 0.79 x $3,491.10	--	2,757.97	--
		7,768.18	5.48
Variable costs:[3]			
Fuel	--	--	.50
Engine oil	--	--	.03
Filters	--	--	.01
Lubrication	--	--	.02
Wire rope, $\frac{6.3}{8}$ or 0.79 x $120.18	--	94.94	.07
Labor	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	10.44
Total per minute	0.174	--	--

[1] Horsepower is net engine horsepower; 6.3-hour day is for contractor crew where loading takes 1.7 hours per day away from yarding operation.
[2] At 225 days x 6.3 hours = 1,418 hours per year.
[3] Derived from table 6.

Table 8.—Machine rate, 50-hp. crawler tractor with arch, based on 8-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
		Dollars	
List price, including freight[3]	14,950.00	--	--
Rubber-tired arch, used	600.00	--	--
Residual value, 10 percent of initial price	1,555.00	--	--
Amount to be depreciated	13,995.00	--	--
Average investment for imputed interest[4] $\frac{I+R}{2} = \frac{\$17{,}105}{2}$	8,552.50	--	--
Average investment for insurance and taxes[4] $\frac{I+R+D}{2} = \frac{\$19{,}904}{2}$	9,952.00	--	--
Fixed costs:			
Depreciation, 5 years $\frac{\$13{,}995}{5}$	--	2,799.00	--
Imputed interest, 6 percent of average investment	--	513.15	--
Insurance, 1 percent of average investment	--	99.52	--
Taxes, 2 percent of average investment	--	199.04	--
Repairs and maintenance, 90 percent of depreciation	--	2,519.10	--
Imputed interest on choker investment, 6 percent x $10.50 x 10	--	6.30	--
	--	6,136.11	3.41
Variable costs:			
Fuel, 2.5 gallons per hour x $0.16	--	--	.40
Engine oil, 0.05 gallon per hour x $0.65	--	--	.03
Filters, estimated	--	--	.01
Lubrication, 0.1 lb. per hour x $0.15	--	--	.02
Wire rope[5]	--	--	.07
Labor, at $3.075 per hour x 1.25 payroll overhead	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	8.27
Total per minute	0.138	--	--

[1] Horsepower is net engine horsepower.
[2] At 225 days x 8 hours = 1,800 hours per year.
[3] Includes blade, canopy, and winch.
[4] I = initial cost; R = residual value; D = depreciation.
[5] From table 6.

Table 9.—Machine rate, 50-hp. crawler tractor with arch, based on 6.3-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
		Dollars	
Fixed costs, less repairs and maintenance[3]	--	3,617.01	--
Repairs and maintenance, $\frac{6.3}{8}$ or 0.79 x $2,519.10	--	1,990.09	--
	--	5,607.10	3.95
Variable costs:[3]			
Fuel	--	--	.40
Engine oil	--	--	.03
Filters	--	--	.01
Lubrication	--	--	.02
Wire rope, $\frac{6.3}{8}$ or 0.79 x $120.18	--	94.94	.07
Labor	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	8.81
Total per minute	0.147	--	--

[1] Horsepower is net engine horsepower; 6.3-hour day is for contractor crew where loading takes 1.7 hours per day away from yarding operation.
[2] At 225 days x 6.3 hours = 1,418 hours per year.
[3] Derived from table 8.

Table 10.—Machine rate, 60-hp. four-wheel skidder, based on 8-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
	Dollars		
List price, including freight[3]	13,627.00	--	--
Residual value, 10 percent of initial price	−1,362.70	--	--
Amount to be depreciated	12,264.30	--	--
Average investment for imputed interest[4] $\frac{I+R}{2} = \frac{\$14,989.70}{2}$	7,494.85	--	--
Average investment for insurance and taxes[4] $\frac{I+R+D}{2} = \frac{\$17,442.56}{2}$	8,721.28	--	--
Fixed costs:			
Depreciation, 5 years $\frac{\$12,264.30}{5}$	--	2,452.86	--
Imputed interest, 6 percent of average investment	--	449.69	--
Insurance, 1 percent of average investment	--	87.21	--
Taxes, 2 percent of average investment	--	174.43	--
Repairs and maintenance, 90 percent of depreciation	--	2,207.57	--
Imputed interest on choker investment, 6 percent x $10.50 x 10	--	6.30	--
	--	5,378.06	2.99
Variable costs:			
Fuel, 2 gallons per hour x $0.16	--	--	.32
Engine oil, 0.05 gallon per hour x $0.65	--	--	.03
Filters	--	--	.01
Lubrication 0.1 lb. per hour x $0.15	--	--	.02
Hydraulic oil, estimated	--	--	.01
Wire rope[5]	--	--	.07
Labor, at $3.075 per hour x 1.25 payroll overhead	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	7.78
Total per minute	0.130	--	--

[1] Horsepower is net engine horsepower.
[2] At 225 days x 8 hours = 1,800 hours per year.
[3] Includes blade, canopy, and winch.
[4] I = initial cost; R = residual value; D = depreciation.
[5] From table 6.

Table 11.—Machine rate, 60-hp. four-wheel skidder, based on 6.3-hour day, 1965[1]

Item	Amount	Per year	Per hour[2]
	Dollars		
Fixed costs, less repairs and maintenance[3]	--	3,170.49	--
Repairs and maintenance, $\frac{6.3}{8}$ or 0.79 x $2,207.57	--	1,743.98	--
	--	4,914.47	3.47
Variable costs:[3]			
Fuel	--	--	.32
Engine oil	--	--	.03
Filters	--	--	.01
Lubrication	--	--	.02
Hydraulic oil	--	--	.01
Wire rope, $\frac{6.3}{8}$ or 0.79 x $120.18	--	94.94	.07
Labor	--	--	3.84
Crew transportation	--	--	.49
Total per hour	--	--	8.26
Total per minute	0.138	--	--

[1] Horsepower is net engine horsepower; 6.3-hour day is for contractor crew where loading takes 1.7 hours per day away from yarding operation.
[2] At 225 days x 6.3 hours = 1,418 hours per year.
[3] Derived from table 10.

Table 12.—Machine rate, 1-yard rubber-tired loader, with heel boom and grapple, based on 8-hour day, 1965

Item	Amount	Per year	Per day	Per hour[1]
	Dollars			
List price, less tires, including freight	78,000.00	--	--	--
Residual value, 20 percent of initial price	–15,600.00	--	--	--
Amount to be depreciated	62,400.00	--	--	--
Initial tire cost, ten 10x20 at \$123.43	1,234.30	--	--	--
Average investment for imputed interest[2] $\frac{I+R}{2} = \frac{\$94{,}834.30}{2}$	47,417.15	--	--	--
Average investment for insurance and taxes[2] $\frac{I+R+D}{2} = \frac{\$101{,}321.16}{2}$	50,660.58	--	--	--
Fixed costs:				
Depreciation, less tires, 10 years $\frac{\$62{,}400}{10}$	--	6,240.00	--	--
Depreciation on tires (replace in 5 years) $\frac{\$1{,}234.30}{5}$	--	246.86	--	--
	--	6,486.86	--	--
Imputed interest, 6 percent of average investment	--	2,845.03	--	--
Insurance, 1 percent of average investment	--	506.61	--	--
Taxes, 2 percent of average investment	--	1,013.21	--	--
Repairs and maintenance, 50 percent of depreciation	--	3,243.43	--	--
	--	14,095.14	--	7.83
Variable costs:				
Fuel, 7 gallons per hour x \$0.16	--	--	--	1.12
Lubrication and oil, estimated	--	--	--	.04
Cable replacement, closing cable, every 25 days ¾-inch, 90 feet $= \frac{\$45.69}{25}$	--	--	1.83	--
Cable replacement, opening cable, every 50 days 5/8-inch, 90 feet $= \frac{\$32.64}{50}$	--	--	.65	--
	--	--	2.48	.31
Labor, engineer at \$3.23 and head loader at \$3.16 = \$6.39 x 1.25 payroll overhead	--	--	--	7.99
Crew transportation, \$0.98 per hour	--	--	--	.98
Total per hour	--	--	--	18.27
Total per minute	.304	--	--	--

[1] At 225 days x 8 hours = 1,800 hours per year.
[2] I = initial cost; R = residual value; D = depreciation.

Table 13.—Machine rate, 3/4-yard track-mounted loader, with heel boom and grapple, based on 1.7-hour day, 1965

Item	Amount	Per year	Per day	Per hour[1]
	Dollars			
List price, used (estimated one-third of new)	12,500.00	--	--	--
Residual value, 10 percent of initial price	–1,250.00	--	--	--
Amount to be depreciated	11,250.00	--	--	--
Average investment for imputed interest[2] $\frac{I+R}{2} = \frac{\$13{,}750}{2}$	6,875.00	--	--	--
Average investment for insurance and taxes[2] $\frac{I+R+D}{2} = \frac{\$14{,}875}{2}$	7,437.50	--	--	--
Fixed costs:				
Depreciation, 10 years $\frac{\$11{,}250}{10}$	--	1,125.00	--	--
Imputed interest, 6 percent of average investment	--	412.50	--	--
Insurance, 1 percent of average investment	--	74.38	--	--
Taxes, 2 percent of average investment	--	148.75	--	--
Repairs and maintenance, 75 percent of depreciation	--	843.75	--	--
	--	2,604.38	--	6.81
Variable costs:				
Fuel, 3 gallons per hour x \$0.16	--	--	--	.48
Lubrication and oil, estimated	--	--	--	.03
Cable replacement, closing cable, every 120 days 5/8-inch, 90 feet $= \frac{\$32.64}{120}$	--	--	.27	--
Cable replacement, opening cable, every 240 days 1/2-inch, 90 feet $= \frac{\$26.04}{240}$	--	--	.11	--
	--	--	.38	.22
Labor, engineer at \$3.075 and head loader at \$2.85 = \$5.93 x 1.25 payroll overhead	--	--	--	7.41
Crew transportation, \$0.98 per hour	--	--	--	.98
Total per hour	--	--	--	15.93
Total per minute	0.266	--	--	--

[1] At 225 days x 1.7 hours per day = 382.5 hours per year.
[2] I = initial cost; R = residual value; D = depreciation.

Table 14.—Machine rate, medium chain saw, 24-inch bar, based on 8-hour day, 1965

Item	Amount	Per year	Per day	Per hour[1]
	Dollars			
List price	250.00	--	--	--
Residual value, estimated	−50.00	--	--	--
Amount to be depreciated	200.00	--	--	--
Spare saw, used	85.00	--	--	--
Average investment for imputed interest[2] $\frac{I+R}{2} = \frac{\$385}{2}$	192.50	--	--	--
Average investment for taxes[2] $\frac{I+R+D}{2} = \frac{\$385 + \$95}{2}$	240.00	--	--	--
Fixed costs:				
Depreciation, 3 years $\frac{\$200 + \$85}{3} = \frac{\$285}{3}$	--	95.00	--	--
Imputed interest, 6 percent of average investment	--	11.55	--	--
Taxes, 2 percent of average investment	--	4.80	--	--
Repairs and maintenance, 90 percent of depreciation	--	85.50	--	--
Chain replacement, 4 per year at $30	--	120.00	--	--
Bar replacement, 1 per year at $30	--	30.00	--	--
Miscellaneous tools and equipment	--	50.00	--	--
	--	396.85	--	0.22
Variable costs:				
Fuel, 1.5 gallons per day at $0.32	--	--	0.48	--
Chain oil, 1 quart per day	--	--	.30	--
Lubricating oil for fuel mixture, 0.75 pint per day at $0.70	--	--	.52	--
	--	--	1.30	.16
	--	--	--	.38
Labor, $3.75 x 1.25 payroll overhead	--	--	--	4.69
Crew transportation	--	--	--	.49
Total per hour	--	--	--	5.56
Total per minute	0.0927	--	--	--

[1] At 225 days x 8 hours = 1,800 hours per year.
[2] I = initial cost; R = residual value; D = depreciation.

Table 15.—Machine rate, 1/2-ton pickup truck, 1965

Item	Amount	Per year	Per day	Per hour[1]
		Dollars		
List price	3,080.00	--	--	--
Residual value, 20 percent of initial price	−616.00	--	--	--
Amount to be depreciated	2,464.00	--	--	--
Average investment for imputed interest[2] $\frac{I+R}{2} = \frac{\$3,696}{2}$	1,848.00	--	--	--
Average investment for insurance and taxes[2] $\frac{I+R+D}{2} = \frac{\$4,188.80}{2}$	2,094.40	--	--	--
Fixed costs:				
Depreciation, 5 years $\frac{\$2,464}{5}$	--	492.80	--	--
Imputed interest, at 6 percent of average investment	--	110.88	--	--
Insurance, estimated at 5 percent of average investment	--	104.72	--	--
Taxes, at 2 percent of average investment	--	41.89	--	--
License fee	--	10.00	--	--
Repairs and maintenance, 90 percent of depreciation	--	443.52	--	--
Tires and tubes, 4 per year at $35	--	140.00	--	--
	--	1,343.81	5.97	--
Variable costs:				
Fuel, 12 miles per gallon, 60 miles per day, or 5 gallons per day x $0.32	--	--	1.60	--
Lubrication, 15 percent of fuel cost	--	--	.24	--
Oil filter replacement, $3.50 every 4,000 miles	--	--	.05	--
	--	--	7.86	.98

[1] At 225 days x 8 hours = 1,800 hours per year.
[2] I = initial cost; R = residual value; D = depreciation.

Table 16.—Skidding-cycle time in Douglas-fir thinning operations, 65-hp. crawler tractor, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet) 50	100	200	400	700	1,000
		Minutes per turn					
Cubic feet:							
5	10	26.1	26.6	27.6	29.6	32.5	35.5
10	10	26.6	27.1	28.1	30.1	33.0	36.0
25	10	28.0	28.5	29.5	31.5	34.4	37.4
50	6	18.9	19.4	20.4	22.4	25.5	28.6
100	3	12.7	13.2	14.2	16.2	19.1	22.1
200	1.5	9.9	10.4	11.4	13.4	16.3	19.3
300	1	8.9	9.4	10.4	12.4	15.3	18.3
Board feet:[2]							
20	10	26.6	27.1	28.1	30.1	33.0	36.0
50	10	27.0	27.5	28.5	30.5	33.4	36.4
100	10	27.7	28.2	29.2	31.2	34.1	37.1
200	7.5	22.1	22.6	23.6	25.6	28.5	31.5
500	3	12.0	12.5	13.5	15.5	18.4	21.4
1,000	1.5	8.8	9.3	10.3	12.3	15.2	18.2

[1] Based on 200 trees per acre before cut, 30 trees cut per acre, and tractor operator's setting and releasing chokers. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 17.—Skidding cost per unit volume in Douglas-fir thinning operations, 65-hp. crawler tractor, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet) 50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	11.64	11.86	12.30	13.20	14.50	15.84
10	10	5.93	6.04	6.27	6.71	7.36	8.03
25	10	2.50	2.54	2.63	2.81	3.07	3.34
50	6	1.40	1.44	1.52	1.67	1.90	2.13
100	3	.94	.98	1.06	1.20	1.42	1.64
200	1.5	.74	.77	.85	1.00	1.21	1.43
300	1	.66	.70	.77	.92	1.14	1.36
Board feet:[2]		Dollars per M board feet					
20	10	29.65	30.20	31.35	33.55	36.80	40.15
50	10	12.04	12.26	12.72	13.60	14.90	16.24
100	10	6.18	6.29	6.51	6.96	7.60	8.27
200	7.5	3.29	3.36	3.51	3.81	4.24	4.68
500	3	1.79	1.86	2.01	2.31	2.73	3.18
1,000	1.5	1.31	1.38	1.53	1.83	2.26	2.71

[1] Based on cost of \$0.161 per minute x 1.385 delay factor = \$0.223 per minute. Cost per unit volume = $\frac{\text{minutes per turn x cost per minute}}{\text{volume per turn}}$. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 18.—Skidding-cycle time in Douglas-fir thinning operations, 50-hp. crawler tractor, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet) 50	100	200	400	700	1,000
		Minutes per turn					
Cubic feet:							
5	10	20.3	20.7	21.5	23.1	25.5	28.0
10	10	21.3	21.7	22.5	24.1	26.5	29.0
25	6	14.6	15.0	15.8	17.4	19.8	22.3
50	3	9.5	9.9	10.7	12.3	14.7	17.2
100	1.5	6.9	7.3	8.1	9.7	12.1	14.6
150	1	6.0	6.4	7.2	8.8	11.2	13.7
Board feet:[2]							
20	10	20.3	20.7	21.4	23.0	25.4	27.8
50	10	21.2	21.6	22.3	23.9	26.3	28.7
100	7	16.5	16.9	17.6	19.2	21.6	24.0
200	3.5	10.5	10.9	11.6	13.2	15.6	18.0
500	1.4	6.6	7.0	7.7	9.3	11.7	14.1
700	1	6.2	6.6	7.3	8.9	11.3	13.7

[1] Based on 200 trees per acre before cut, 30 trees cut per acre, and tractor operator's setting and releasing chokers. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 19.—Skidding cost per unit volume in Douglas-fir thinning operations, 50-hp. crawler tractor, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet) 50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	8.28	8.44	8.78	9.42	10.40	11.42
10	10	4.35	4.43	4.59	4.92	5.41	5.92
25	6	1.99	2.04	2.15	2.37	2.69	3.03
50	3	1.29	1.35	1.45	1.67	2.00	2.34
100	1.5	.94	.99	1.10	1.32	1.65	1.99
150	1	.82	.87	.98	1.20	1.52	1.86
Board feet:[2]		Dollars per M board feet					
20	10	20.70	21.10	21.82	23.45	25.90	28.35
50	10	8.64	8.82	9.10	9.76	10.74	11.70
100	7	4.81	4.93	5.13	5.60	6.30	7.00
200	3.5	3.06	3.17	3.39	3.84	4.54	5.24
500	1.4	1.93	2.04	2.24	2.71	3.41	4.11
700	1	1.80	1.93	2.13	2.60	3.30	3.99

[1] Based on cost of \$0.147 per minute x 1.385 delay factor = \$0.204 per minute. Cost per unit volume = $\frac{\text{minutes per turn x cost per minute}}{\text{volume per turn}}$. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 20.—Skidding-cycle time in Douglas-fir thinning operations, 60-hp. four-wheel skidder, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet)					
		50	100	200	400	700	1,000
		Minutes per turn					
Cubic feet:							
5	10	18.9	19.2	19.9	21.2	23.0	24.9
10	10	19.4	19.7	20.4	21.7	23.5	25.4
25	6	14.1	14.4	15.1	16.4	18.2	20.1
50	3	9.8	10.1	10.8	12.1	13.9	15.8
100	1.5	7.6	7.9	8.6	9.9	11.7	13.6
150	1	6.9	7.2	7.9	9.2	11.0	12.9
Board feet:[2]							
20	10	18.9	19.3	19.9	21.2	23.2	25.1
50	10	19.4	19.8	20.4	21.7	23.7	25.6
100	7	15.3	15.7	16.3	17.6	19.6	21.5
200	3.5	10.2	10.6	11.2	12.5	14.5	16.4
500	1.4	7.4	7.8	8.4	9.7	11.7	13.6
700	1	6.7	7.1	7.7	9.0	11.0	12.9

[1] Based on 200 trees per acre before cut, 30 trees cut per acre, and tractor operator's setting and releasing chokers. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 21.—Skidding cost per unit volume in Douglas-fir thinning operations, 60-hp. four-wheel skidder, by log volume, 1965[1]

Volume per log	Number of logs per turn	Slope distance (feet)					
		50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	7.22	7.34	7.60	8.10	8.78	9.52
10	10	3.71	3.76	3.90	4.14	4.49	4.85
25	6	1.79	1.83	1.92	2.09	2.32	2.56
50	3	1.25	1.29	1.37	1.54	1.77	2.01
100	1.5	.97	1.01	1.09	1.26	1.49	1.73
150	1	.88	.92	1.01	1.17	1.40	1.64
Board feet:[2]		Dollars per M board feet					
20	10	18.05	18.45	19.00	20.25	22.15	23.95
50	10	7.42	7.56	7.80	8.28	9.06	9.78
100	7	4.17	4.28	4.44	4.80	5.34	5.87
200	3.5	2.78	2.88	3.06	3.41	3.96	4.47
500	1.4	2.01	2.13	2.28	2.64	3.18	3.71
700	1	1.83	1.94	2.10	2.46	3.00	3.51

[1] Based on cost of \$0.138 per minute x 1.385 delay factor = \$0.191 per minute. Cost per unit volume = $\frac{\text{minutes per turn x cost per minute}}{\text{volume per turn}}$. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 22.—Total direct logging cost per unit volume in Douglas-fir thinning operations, by skidding slope distance, 65-hp. crawler tractor, 1965[1]

Volume per log	Number of logs per turn	Skidding slope distance (feet)					
		50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	28.15	28.37	28.81	29.71	31.01	32.35
10	10	17.44	17.55	17.78	18.22	18.87	19.24
25	10	10.70	10.74	10.83	11.01	11.27	11.54
50	6	8.24	8.28	8.36	8.51	8.74	8.97
100	3	7.32	7.36	7.44	7.58	7.80	8.02
150	2	7.05	7.09	7.16	7.31	7.53	7.75
Board feet:[2]		Dollars per M board feet					
20	10	68.26	68.81	69.96	72.16	75.41	78.76
50	10	38.26	38.48	38.94	39.82	41.12	42.46
100	10	24.66	24.77	24.99	25.44	26.08	26.75
200	7.5	17.48	17.55	17.70	18.00	18.43	18.87
500	3	13.06	13.13	13.28	13.58	14.00	14.45

[1] Includes felling and bucking, skidding, loading, and hauling 30 miles. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 23.—Total direct logging costs per unit volume in Douglas-fir thinning operations, by skidding slope distance, 50-hp. crawler tractor, 1965[1]

Volume per log	Number of logs per turn	Skidding slope distance (feet)					
		50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	28.79	28.95	29.29	29.93	30.91	31.93
10	10	17.86	17.94	18.10	18.43	18.92	19.43
25	6	10.99	11.04	11.15	11.37	11.69	13.55
50	3	8.53	8.59	8.69	8.91	9.24	9.58
100	1.5	7.52	7.57	7.68	7.90	8.23	8.57
150	1	7.15	7.21	7.32	7.54	7.86	8.20
Board feet:[2]		Dollars per M board feet					
20	10	69.31	69.71	70.46	72.06	74.51	76.96
50	10	38.86	39.04	39.32	39.98	40.96	41.92
100	7	25.29	25.41	25.61	26.08	26.78	27.48
200	3.5	18.25	18.36	18.58	19.03	19.73	20.43
500	1.4	13.60	13.71	13.91	14.38	15.08	15.58

[1] Includes felling and bucking, skidding, loading, and hauling 30 miles. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 24.—Total direct logging costs per unit volume in Douglas-fir thinning operations, by skidding slope distance, 60-hp. four-wheel skidder, 1965[1]

Volume per log	Number of logs per turn	Skidding slope distance (feet) 50	100	200	400	700	1,000
Cubic feet:		Dollars per 100 cubic feet					
5	10	27.73	27.85	28.11	28.61	29.29	30.03
10	10	17.22	17.27	17.41	17.65	18.00	18.36
25	6	10.79	10.83	10.92	11.09	11.32	11.56
50	3	8.49	8.53	8.61	8.78	9.01	9.25
100	1.5	7.55	7.59	7.67	7.84	8.07	8.31
150	1	7.22	7.26	7.35	7.51	7.74	7.98
Board feet:[2]		Dollars per M board feet					
20	10	66.66	67.06	67.61	68.86	70.76	72.56
50	10	37.64	37.78	38.02	38.50	39.28	40.00
100	7	24.65	24.76	24.92	25.28	25.82	26.35
200	3.5	17.97	18.07	18.25	18.60	19.15	19.66
500	1.4	13.68	13.80	13.95	14.31	14.85	15.38

[1] Includes felling and bucking, skidding, loading, and hauling 30 miles. Horsepower is net engine horsepower.
[2] Scribner rule.

Table 25.—Basic hauling cost per trip, 1965[1]

Distance (miles) Sectional	Cumulative	Road type[2]	Time per round-trip mile	Travel time	Cumulative travel time	Cumulative operating cost[3]	Cumulative tire cost[4]	Federal-State highway use tax[5]	Delay cost[6]	Total basic cost	Adjusted basic hauling cost[7]
			Minutes			Dollars					
0.3	0.3	G1	6.33	1.9	1.9	0.40	0.03	0.03	3.11	3.57	4.43
3.7	4.0	G2	4.82	17.8	19.7	4.12	.38	.41	3.11	8.02	9.94
2.0	6.0	P1	4.63	9.3	29.0	6.06	.44	.61	3.11	10.22	12.67
4.0	10.0	P2	3.75	15.0	44.0	9.20	.56	1.01	3.11	13.88	17.21
10.0	20.0	P3	3.60	36.0	80.0	16.72	.87	2.03	3.11	22.73	28.19
10.0	30.0	P4	3.18	31.8	111.8	23.37	1.18	3.04	3.11	30.70	38.07
10.0	40.0	P4	3.18	31.8	143.6	30.01	1.49	4.06	3.11	38.67	47.95
10.0	50.0	P4	3.18	31.8	175.4	36.66	1.80	5.07	3.11	46.64	57.83
10.0	60.0	P4	3.18	31.8	207.2	43.30	2.11	6.08	3.11	54.60	67.70
10.0	70.0	P4	3.18	31.8	239.0	49.95	2.42	7.10	3.11	62.58	77.60

[1] Derived from Logging Road Handbook (Byrnes et al. 1960).
[2] Road types: G1 Gravel, single lane, 8-percent slope; G2 Gravel, 1-1/2 lane, 4-percent slope; P1 Paved highway, 6-percent slope; P2 Paved highway, 4-percent slope; P3 Paved highway, 3-percent slope; P4 Paved highway, 2-percent slope
[3] Operating cost = \$0.2090 per minute (0.0298 fixed cost + \$0.1202 operating cost + \$0.0590 labor cost); excludes tire cost.
[4] Tire cost = \$0.094 per mile on gravel road, \$0.0310 per mile on paved road.
[5] Federal-State highway use tax taken as \$0.1014 per mile.
[6] Delay cost = \$0.0888 per minute for average of 35 minutes for scaling, waiting at landing, etc., or \$3.11 per trip.
[7] Based on adjustment factor of 1.24 for price changes 1959-65.

Table 26.—Supplemental hauling cost per load, 1965[1]

Volume per log	Ratio: bd. ft./cu. ft.	Volume per load	Logs per load	Time per load[2]	Supplemental hauling cost per load at $0.1101 per minute
		Feet	Number	Minutes	Dollars
Cubic feet:					
2.5	--	744	298	60	6.61
5	--	744	149	60	6.61
10	--	744	74	60	6.61
25	--	744	30	33	3.63
50	--	744	15	22	2.42
100	--	744	7.4	[3]21	2.31
150	--	744	5	[3]18	1.98
Board feet:[4]					
10	3.3	2,455	246	60	6.61
20	4.0	2,976	149	60	6.61
50	4.2	3,125	62	55	6.06
100	4.6	3,422	34	36	3.96
200	5.1	3,794	19	26	2.86
500	6.3	4,687	9.4	19	2.09
1,000	7.1	5,282	5.3	[3]19	2.09
1,500	7.6	5,654	3.8	[3]17	1.87

[1] Supplemental hauling cost is the cost of truck and driver during loading time.
[2] At 0.6 minute per log direct loading time plus 11.4 minutes fixed time per load, multiplied by 1.123 delay factor. Maximum time per load taken as 60 minutes.
[3] At 1.0 minute instead of 0.6 minute per log direct loading time.
[4] Scribner rule.

Table 27.—Total hauling cost, related to cubic-foot log volumes, 1965

Cost basis and hauling distance (miles)	For log volumes (cubic feet) of						
	2.5	5	10	25	50	100	150
	Dollars						
Per trip:							
10	23.82	23.82	23.82	20.84	19.63	19.52	19.19
20	34.80	34.80	34.80	31.82	30.61	30.50	30.17
30	44.68	44.68	44.68	41.70	40.49	40.38	40.05
40	54.56	54.56	54.56	51.58	50.37	50.26	49.93
50	64.44	64.44	64.44	61.46	60.25	60.14	59.81
60	74.31	74.31	74.31	71.33	70.12	70.01	69.68
70	84.21	84.21	84.21	81.23	80.02	79.91	79.51
Per 100 cubic feet:							
10	3.20	3.20	3.20	2.80	2.64	2.62	2.58
20	4.68	4.68	4.68	4.28	4.11	4.10	4.06
30	6.01	6.01	6.01	5.60	5.44	5.43	5.38
40	7.33	7.33	7.33	6.93	6.77	6.76	6.71
50	8.65	8.65	8.65	8.26	8.10	8.08	8.04
60	9.99	9.99	9.99	9.59	9.42	9.41	9.37
70	11.32	11.32	11.32	10.92	10.76	10.74	10.69

Table 28.—Total hauling cost, related to board-foot log volumes, 1965

Cost basis and hauling distance (miles)	For log volumes (board feet, Scribner rule) of							
	10	20	50	100	200	500	1,000	1,500
	Dollars							
Per trip:								
10	23.82	23.82	23.27	21.17	20.07	19.30	19.30	19.08
20	34.80	34.80	34.25	32.15	31.05	30.28	30.28	30.06
30	44.68	44.68	44.13	42.03	40.93	40.16	40.16	39.94
40	54.56	54.56	54.01	51.91	50.81	50.04	50.04	49.82
50	64.44	64.44	63.89	61.79	60.69	59.92	59.92	59.70
60	74.31	74.31	73.76	71.66	70.56	69.79	69.79	69.57
70	84.21	84.21	83.66	81.56	80.46	79.69	79.69	79.47
Per M board feet:								
10	9.70	8.00	7.45	6.19	5.29	4.12	3.65	3.37
20	14.18	11.69	10.96	9.40	8.18	6.46	5.73	5.32
30	18.20	15.01	14.12	12.28	10.79	8.57	7.60	7.06
40	22.22	18.33	17.28	15.17	13.39	10.68	9.47	8.81
50	26.25	21.64	20.44	18.06	16.00	12.78	11.34	10.56
60	30.27	24.97	23.60	20.94	18.60	14.89	13.21	12.30
70	34.30	28.30	26.77	23.83	21.21	17.00	15.09	14.06

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1967. Production rates in commercial thinning of young-growth Douglas-fir. U.S. Forest Serv. Res. Pap. PNW-41, 35 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oreg.

Time studies were made of the individual steps in the thinning operation, including felling and bucking, skidding, and loading. Calculated times per unit of production were related to log and tree volumes, in both cubic feet and board feet, and to skidding distance, type of equipment, and other variables. These production rates, combined with labor and machine rates, permit estimation of unit costs related to log size.

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The FOREST SERVICE of the U.S. DEPARTMENT OF AGRICULTURE is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives--as directed by Congress--to provide increasingly greater service to a growing Nation.

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